REPORT

MACROECONOMIC BENEFITS OF STANDARDISATION

Evidence from six Northern European countries

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Preface

Menon has been commissioned by six standardisation bodies in the Nordic countries and the Netherlands to study how standardisation is related to productivity and trade. The study was commissioned as a joint initiative by the six standardisation bodies Standards Norway (SN), Danish Standards (DS), Swedish Standards Institute (SIS), Finnish Standards Association (SFS), Icelandic Standards (IST) and Netherlands Standardisation Institute (NEN).

Kristoffer Midttømme has been the partner responsible for the project, while Øyvind Vennerød has been the project manager and Linn Skyum a project collaborator. Jonas Erraia has acted as the internal quality assurance manager.

Menon Economics is a research-based analysis and advisory firm at the intersection of economics and business and industry policy. We offer analysis and advisory services to businesses, organisations, municipalities, county authorities and ministries. Our main focus is on empirical analysis of economic policy, and our staff have economic expertise at a high scientific level.

We thank the standardisation bodies for an exciting assignment.

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April 2023
Øyvind Vennerød
Project manager

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Executive summary

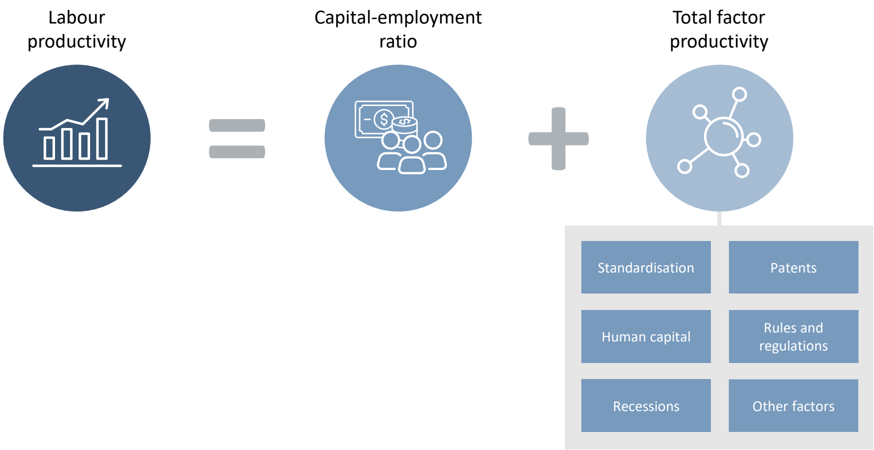
Standards are all around us, and they play a significant role in our lives, even if they are often hard to notice. They improve productivity, facilitate trade between companies, make value chains more efficient, and enhance the quality of products and services. In this report, we analyse the macroeconomic benefits of standardisation in six Northern European countries: the Nordics and the Netherlands.

Standards are associated with productivity growth which increases GDP by 2.6 billion euros annually

The Nordics and the Netherlands have experienced significant productivity growth over the past 50 years. Productivity growth is crucial for both sustainable income growth and poverty reduction. Each employee now produces more than twice as much as they did in 1970, even while working fewer hours. The production per employee is often referred to as *labour productivity.*

Standardisation is one of several factors which affect labour productivity. We use a model of economic growth to estimate how much of the growth in labour productivity comes from standardisation, and how much comes from other sources.

Figure 1: Factors that affect labour productivity



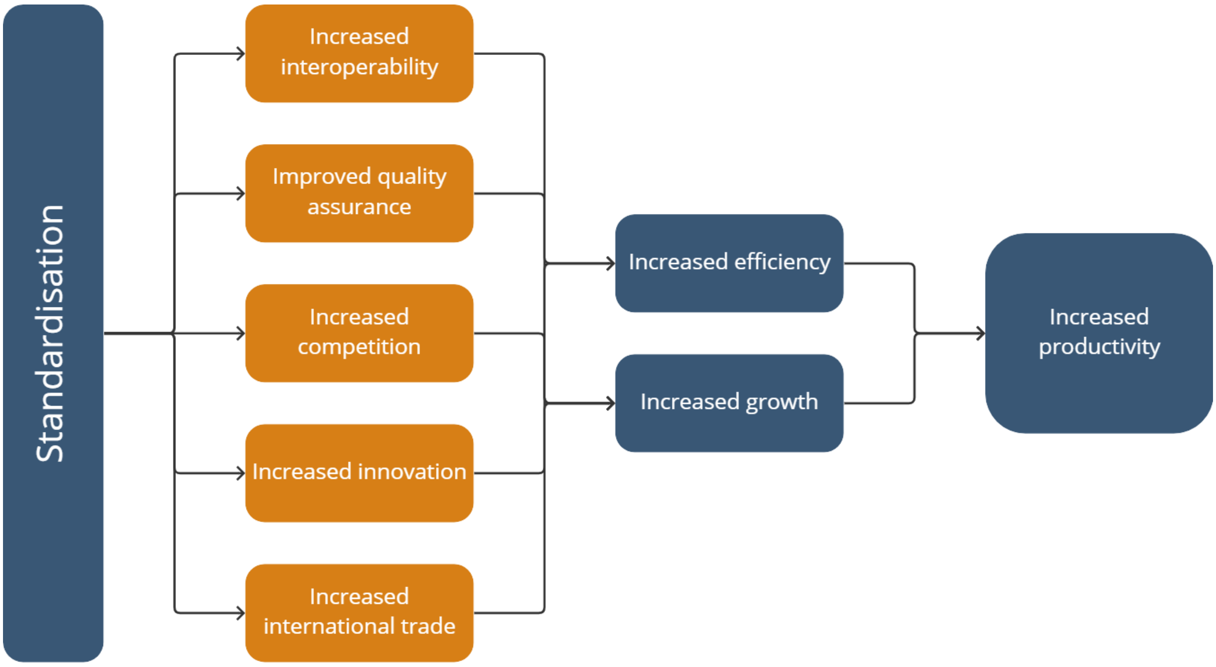
We find that from 1970 to 2019, standardisation was associated with 25 percent of the growth in labour productivity in the six countries. If standardisation work continues at the pace it has for the past decade, this amounts to approximately 2.6 billion euro annually for the six countries combined.

Figure 2: Estimated future annual value added associated with increased standardisation. 2021-prices.

The five main mechanisms that drive productivity growth

We go through the literature and past surveys, and identify five main mechanisms through which standards increase productivity, illustrated in the figure below:

Figure 3: The mechanisms through which standards affect productivity



Standards increase **interoperability** by making products work more seamlessly together, **quality assurance** by ensuring products and services meet specific requirements, and **competition** by providing access to a wide range of state-of-the-art technical information and being accessible to anyone at a relatively low price. They also contribute to **innovation** by establishing a common platform for companies and organisations to build upon. Additionally, standards provide market access for firms to enter international markets and thus drive **international trade**. These mechanisms both increase efficiency and contribute to increased long-term economic growth.

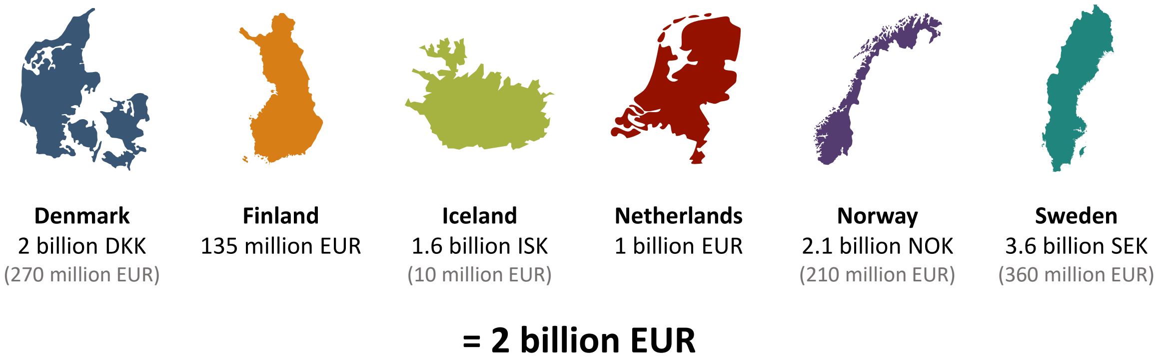
These mechanisms are supported both by economic theory, surveys of thousands of companies, and macroeconomic models.

Standards are associated with an increase in exports of 2 billion euros per year

Market access and international trade is one of the key mechanisms through which standards drive productivity. We employ a gravity model of trade to estimate the contribution of standards to exports from the six countries in this study to sixty-six other countries from 1995 through 2019.

From 1995 to 2019, we find that standards are associated with around 9 percent of the total growth in exports. If standardisation work continues at the pace it has for the past decade, this amounts to approximately 2 billion euro annually for the six countries combined.

Figure 4: Estimated future annual increase in exports associated with increased standardisation



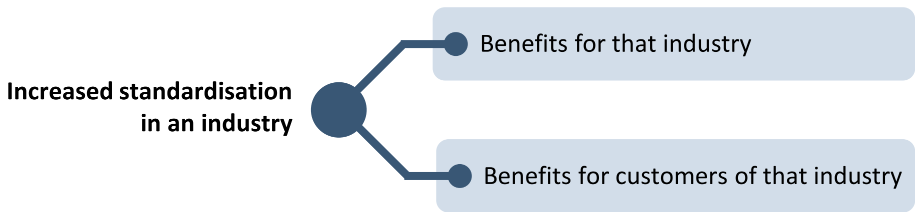
It is important to note that our model assesses the impact of an increase in *industry-specific* standards on exports from that same industry in subsequent years. While this is a crucial aspect of how standards impact trade, it does not capture the whole picture. For instance, our methodology cannot account for the benefits of management standards like ISO 9001 and 14001, which have been shown in past studies to contribute to increased exports. Our model focuses solely on sector-specific benefits, and there are therefore aspects of standards' contribution to trade that it does not consider.

Standards create substantial positive externalities

Standardisation simplifies the purchasing process for customers by ensuring quality, interoperability, and providing a level of quality assurance. We therefore hypothesise that by standardising their products and services, firms create substantial benefits for their customers beyond what they themselves are rewarded for.

We perform a regression analysis to test this hypothesis. The results indicate that standardisation creates gains both for the firm that is doing the standardising and its customers. Since the firms making the decision to standardise are not compensated for all the gains from standardisation, it is likely that there is less standardisation than what is optimal from a social perspective, i.e., that society would benefit if firms dedicated even more resources to standardisation.

Figure 5: Both the industry which standardises and its customers benefit from standardisation



Introduction and reader's guide

Standards are all around us, and they have a significant impact on our lives, even if they are often hard to notice. They facilitate trade between companies, make value chains more efficient, and enhance the quality of products and services. Standards also play a crucial role in making products safer for consumers and protecting workers in the workplace.

In this report, we try to shine a light on how much standards contribute to increased productivity and trade. We do this for a group of six Northern European economies – the Nordics and the Netherlands. All six are highly productive economies, among the 20 most innovative countries in the world and among the 15 most productive.[1] They are also all small, open economies, and thus reliant on exports and rules-based international cooperation. The countries also have active standardisation organisations, long histories of standardisation, and they are among those with the longest high-quality data-series to analyse. This all makes them a particularly interesting group to study.

In chapter 1 of this report, we briefly explain the main mechanisms through which standards contribute to productivity and economic growth. We then provide the results of our regressions between standards and productivity. In chapter 2, we look at how standards contribute to international trade, and model how much standards contribute to increased exports from the six countries. The first two chapters are brief and non-technical, with the goal that all readers should be able to understand their content.

In chapter 3, we go into more detail on the mechanisms through which standards contribute to productivity. We explain why standards contribute to productivity and growth, and the mechanisms that cause the results in chapter 1. This chapter is more complex, but also written in a way that does not require in-depth knowledge of economics or statistics.

In chapter 4, we examine where in the value chain the productivity benefits of standardisation are picked up. In other words, who reaps the benefits of standardisation?

In the appendices, we go through the methodology for this study. These chapters are thorough and in-depth, aimed chiefly at economists, other researchers and those wanting to perform similar analyses in the future.

[1] *Productivity measured by labour productivity, by OECD data for 2021, innovation by the global innovation index for 2021*

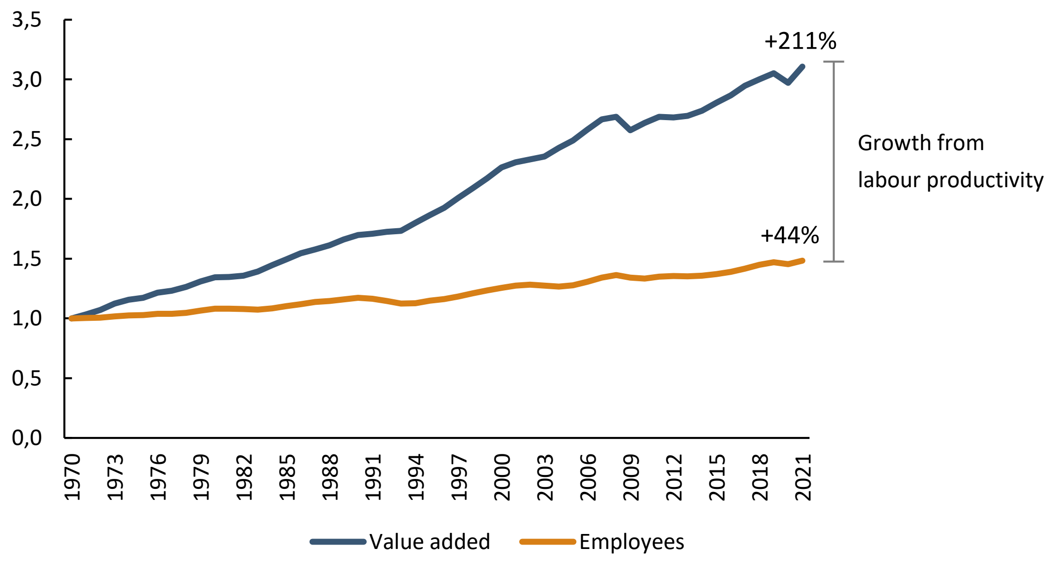
1 Standards' contribution to productivity

The Nordics and the Netherlands have experienced a substantial productivity growth over the past fifty years. This means that each employee produces substantially more today than they did fifty years ago. In 1970, the average value added per employee was below 50 000 euro per year for the group of six. By 2021, the value added had more than doubled to over 100 000 euro.[2] This means that each worker produces more than twice as much now as they did in 1970.

For non-economists, productivity may seem to be an abstract phenomenon, so it is worth emphasising how important productivity growth is. The World Bank puts it as follows: "*Productivity growth is the key driver of sustainable income growth and poverty reduction. Its effects on human welfare are enormous*".[3] Or as Paul Krugman put it: "*Productivity isn't everything, but in the long run, it's **almost** everything".*

From 1970 to 2019, the number of employees in the six countries has grown by approximately 44 percent. Value added however has increased by over 200 percent, meaning that each employee creates substantially more value today. This is the result of labour productivity growth.

Figure 6: Growth in value added and employees from 1970 to 2019 in the region[4]. Source: Menon Economics estimates based on OECD data



So, what has made us so much more productive? A major contributing factor is that we have more *inputs* into the economy, and that these are of a higher quality. Specifically, we have more capital per worker, and the workers are more skilled.

As important as the amount and quality of the inputs into the economy is how well they are utilised. Technological innovations, better institutions, standardisation, increased trade and better regulation have enabled companies to do things today that were impossible 50 years ago, allowing them to become more

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[2] Source: OECD Stat

[3] World Bank (2021). Global Productivity: Trends, Drivers, and Policies - https://www.worldbank.org/en/research/publication/global-productivity

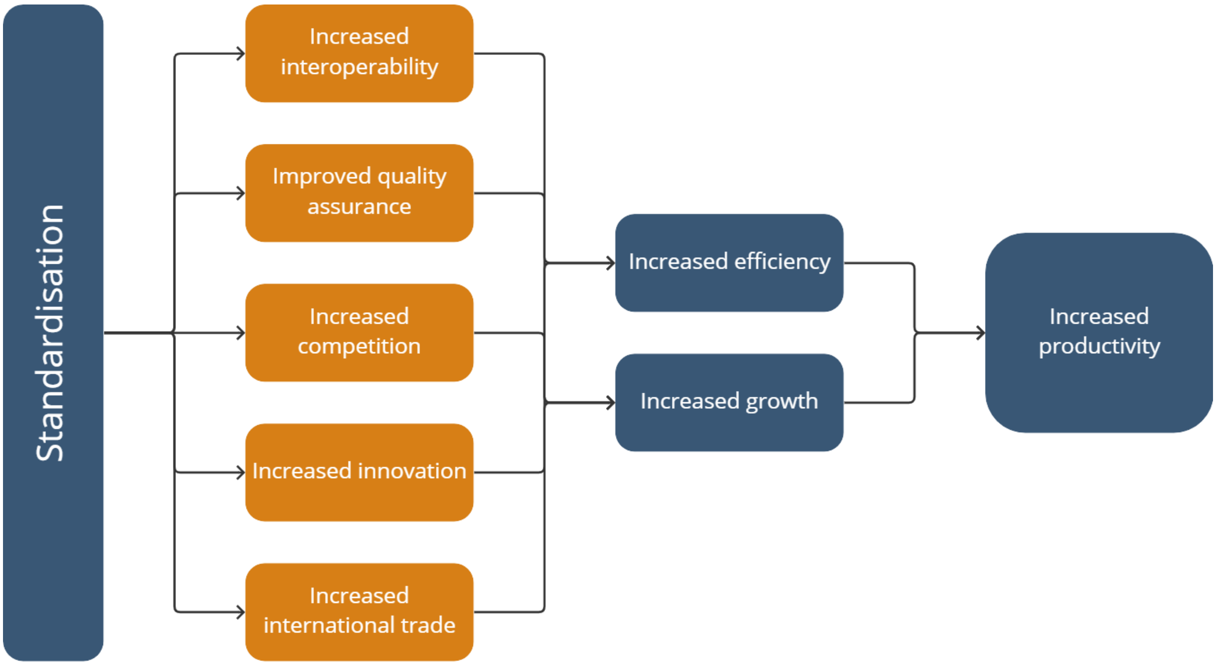
[4] Weighted growth

efficient. In economics, this ability to produce more for a given level of input is known as growth in *total factor productivity (TFP).* There is a broad range of economic literature on what drives total factor productivity. In this report, we use this literature to explore how *standards* affect productivity.

1.1 How do standards affect productivity?

Previous research has highlighted several ways in which standards contribute to increased productivity. Although different reports have different levels of granularity, the underlying mechanisms are the same. We summarise five main mechanisms through which standards increase productivity.

Figure 7: The mechanisms through which standards affect productivity



We delve further into how these mechanisms affect productivity in chapter 2, but present the key insights here.

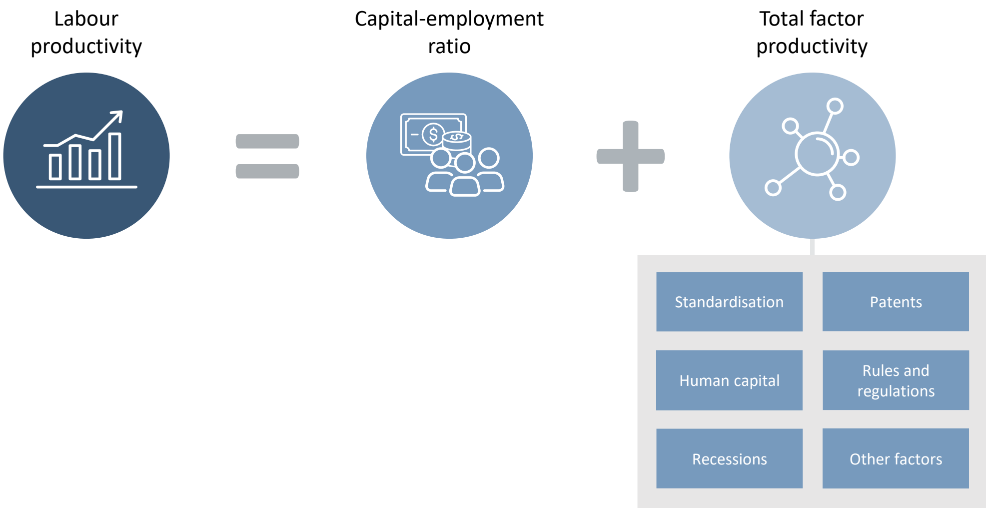
- **Increased interoperability:** Standards provide common rules and specifications which ensure that different systems or devices interact seamlessly.
- **Improved quality assurance:** Standards ensure that products and services meet specific requirements, making them safe, reliable, and high-quality. They also reduce the risk of product failure.
- **Increased competition**: Standards provide access to a wide range of state-of-the-art technical information and are widely accessible to anyone at a relatively low price. This lowers barriers for new companies, and they can more easily enter the market.
- **Increased innovation:** Standardisation creates a common platform for companies and organisations to build upon. Standards push more firms up to the research frontier, and thereby increase the number of firms which can make new innovations.
- **Increased trade:** International standards form a common framework between different countries. This promotes cross-border compatibility and reduces barriers to international trade. Standards are for this reason often a basis for international trade agreements, as they can provide a common ground for different countries to agree upon.

These factors contribute to both increased efficiency in the short term, and to increased growth for the future.

1.2 The productivity model

To measure the productivity benefits of standardisation, we employ a methodology from macroeconomic theory where we estimate the contribution of each of the different factors which are thought to increase labour productivity. Figure 8 below shows the general outline of how these analyses work.

Figure 8: Factors that affect labour productivity[5]



Labour productivity – which is another term for how much each worker produces – is a result of the amount of capital behind each worker (capital-employment ratio), as well as the TFP. The latter is in turn driven by several other factors, which include human capital, patents, standardisation, institutions, and more. We are chiefly interested in the benefits of standardisation in this analysis.

As a measure of standards, we use the *net stock of standards.* This is the most commonly used metric for standards in the literature. The net stock of standards is the number of standards that are valid in a country at a given time.[6] We have developed this metric by collecting data on implemented standards from each of the six standardisation organisations.

Below, we show two figures illustrating the development of the net stock of standards. The first of these, Figure 9, illustrates the average yearly growth *rate* in the stock of standards.

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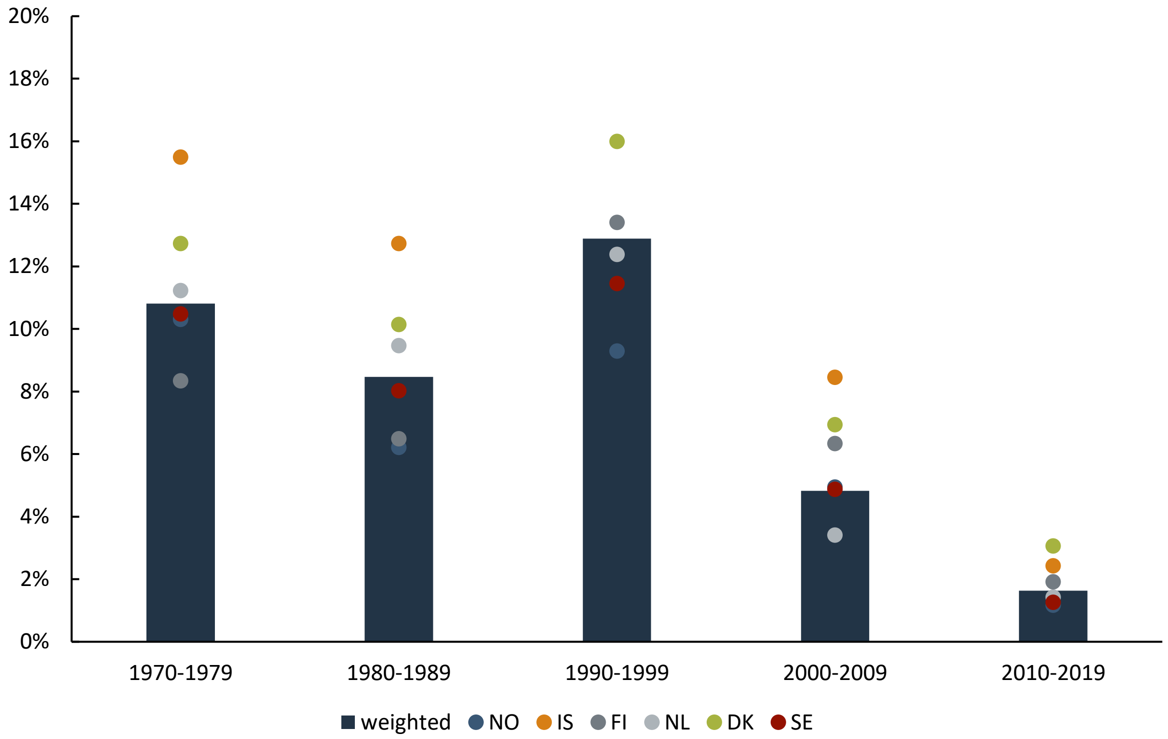
[5] *Cobb-Douglas production function in the style of Blind & Jungmittag (2008), Hogan et al. (2015) and Menon Economics (2018). We further go through the methodology in appendix A.*

[6] *The stock of standards in a year is calculated as the total number of standards which are published up to that year, minus all which have been withdrawn. It is not a perfect measure of the contribution of standards, as it is unable to pick up some important nuances, such as the fact that some standards are more important than others. The stock of standards is, however, the best measure the literature has managed to create so far.*

Standards are continually revised, with new versions replacing old ones. Since revised standards replace old ones (which are then withdrawn), a revision does not affect the net stock of standards, despite standardisation progress having been made. This does, however, not substantially affect the results of analyses such as this one. For more insight on the revision of standards and the stock of standards, see appendix 2.3 of (EY, Menon Economics & Knowence, 2021).

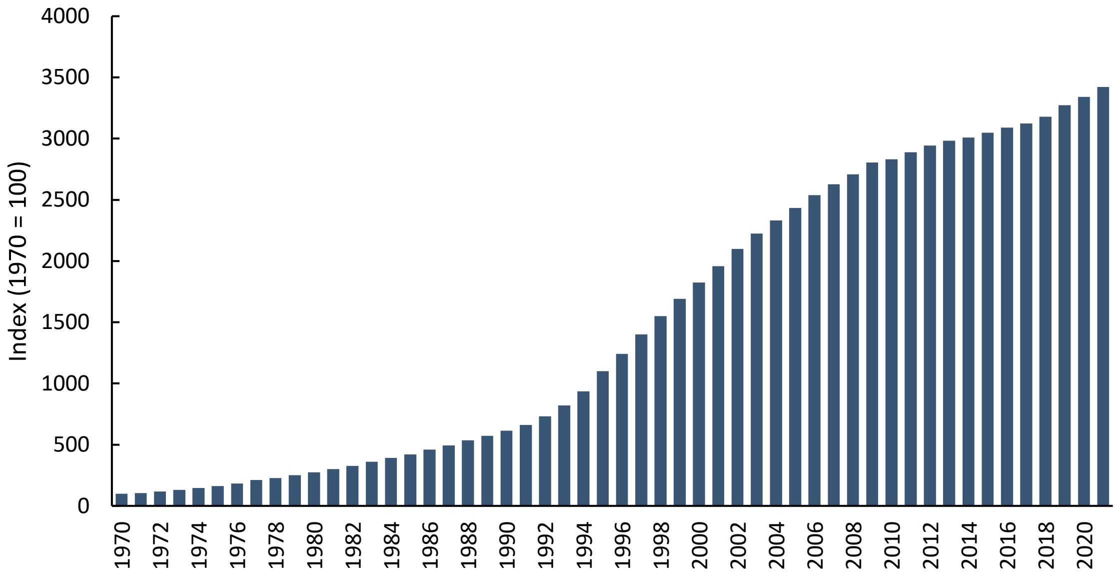
Figure 9: Average yearly growth in the net stock of standards by decade (percent). Weighted average is weighted by country size.[7]



In general, the growth rate of the net stock of standards has decreased from the 1970s to today. There is some variation between the individual countries, but they generally show a similar trend. The number of new standards per year has not fallen, but since the total number of standards has increased, the growth rate has tended to fall. Figure 10 below shows the indexed number of standards, indexed to 100 in 1970.

[7] *Weighted by the countries' GDP per year. Iceland had a growth of over 50 percent in the stock of standards in the 1990s. This datapoint is omitted from the graph.*

Figure 10: Indexed stock of standards per year for the six countries combined. Weighted by the size of the countries economies.



While Figure 9 looked at the growth rates, Figure 10 looks at the absolute number of standards. There was a significant shift in the trend in the late 80s and early 90s. The high growth in this period was mainly due to the establishment of the European Economic Area (EEA) in 1985, which resulted in significant changes to the rules of the European standardisation organizations CEN and CENELEC. The policy approach "New Approach" was launched, which aimed to harmonise technical regulations and standards across EEA member states, in order to reduce technical trade barriers and promote the free movement of goods and services. This included an obligation to implement all European Standards in all EEA countries and an obligation to withdraw all conflicting national standards. Consequently, the stock of standards in European countries increased substantially, also for the six countries we are looking at.

Under the new approach, the EU has also established essential requirements for products, and industry can comply with these requirements by following voluntary harmonized standards[8]. These standards are developed by the European organisations CEN and CENELEC and based on a consensus of all stakeholders.

While the number of new standards has continued to rise at a relatively fast pace during the late 2000s and 2010s, the growth rate has since slowed down. This can be attributed to the substantial increase in the base from which they are growing.

1.2.1 Modelling standards' contribution to productivity growth

A wide range of studies have analysed the productivity benefits of standards, using similar methodology. We go into detail on the methodology in appendix A, but outline the core insights in this section.

[8] A harmonised standard is a technical standard developed by the EU standardisation organisations and recognized by the European Union (EU) as meeting the essential requirements of a relevant EU directive. Harmonized standards are used to show compliance with the requirements of EU directives related to product safety, health, or environmental protection. They are voluntary and provide a way for manufacturers to demonstrate that their products meet EU requirements without the need for further testing or inspection.

The methodology for analysing the economic benefits of standardisation largely builds on models popularised by Blind (2000). The model is based on one of the most central macroeconomic models for economic growth created by Cobb & Douglas in 1928 (Cobb & Douglas, 1928). Over the past 20 years, the methodology popularised by Blind (2000) has since been the most commonly applied model to estimate the productivity benefits of standardisation.

The model provides an estimate of how much an increase in the stock of standards affects labour productivity, after controlling for other factors included in the model. Certain factors which contribute to productivity are not measurable directly – such as the benefits of rules and regulations, learning-by-doing, and more – and therefore cannot be included in the regression model. To pick up as many of these unobservable variables as possible, we include both country-fixed and time-fixed effects in the regression.

Direction of causality

The causality between labour productivity and standardisation may go both ways. Increased standardisation can cause increased productivity growth, but increased productivity may also result in more standardisation. What we investigate in this study is whether an increase in the net stock of standards is *associated* with higher productivity.

While we cannot prove the direction of causality, it appears likely that there is a *larger* effect from standardisation to productivity than vice versa. This is supported by tests we perform in appendix A.

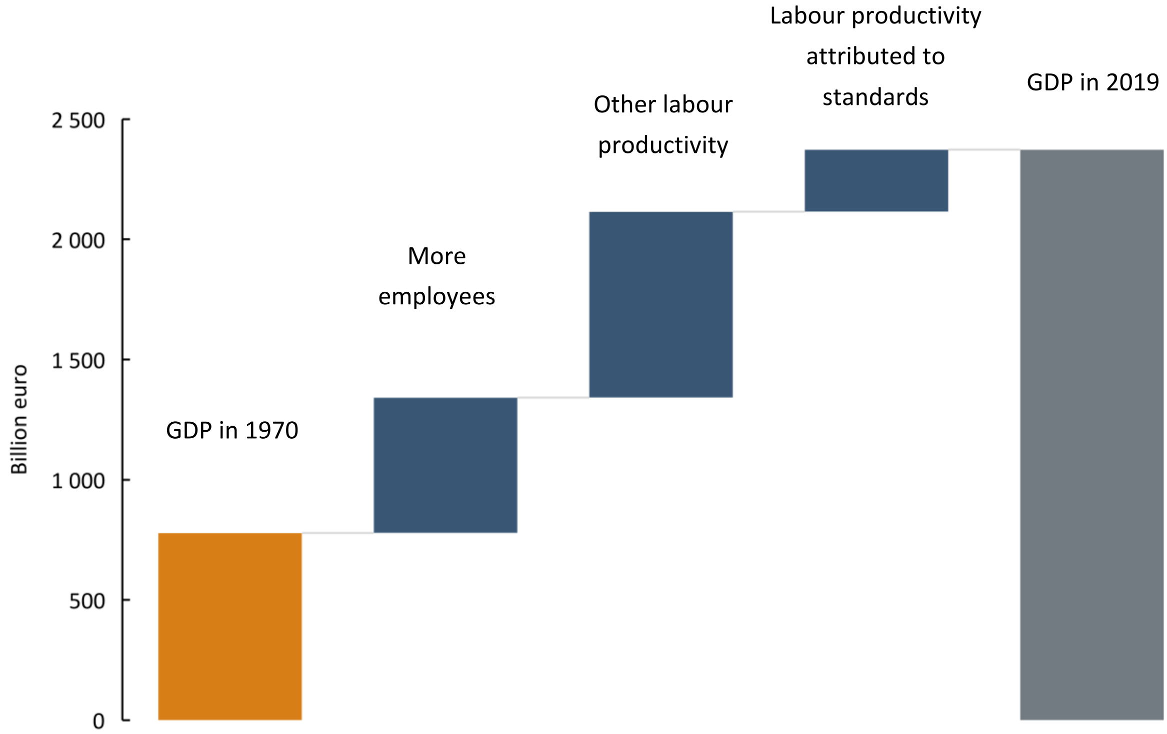
A second point is that other, unobserved factors affecting productivity may also be correlated with the stock of standards. This means that parts of the relation between standardisation and productivity may be due to other factors affecting both standards and productivity.

We go further into the discussion of causality in appendix A.

1.3 The productivity results

Our regression results indicate that a 1 percent increase in the net stock of standards is associated with a 0.06 percent increase in labour productivity. From 1970 to today, the stock of standards has increased by approximately 7 percent per year, which indicates that standards have contributed to a growth in labour productivity of a little over 0.4 percent per year. These results therefore indicate that around a quarter of the growth in labour productivity over the past 50 years is associated with standards. In the figure below, we show the contributions of growth in labour productivity by different sources for the group of six countries.

Figure 11: GDP in 1970 and 2019. Estimated sources of increase from 1970 to 2019. Constant 2015-euro. Source: Menon Economics



The figure can be read as follows: The orange bar in the figure shows the GDP in 1970, while the grey bar shows the GDP in 2019. The blue bars in between show the contribution of the different factors. Growth in the labour stock (more employees) has contributed to slightly over a third of the growth in GDP, while increased productivity per worker has contributed to the rest. Of the growth in labour productivity, our results indicate that standards are associated with around a quarter. This means that of the total growth in output, standards are associated with around 16 percent.

1.3.1 Comparison with other studies

The results we find are broadly in line with previous studies. The table below shows a series of other, recent studies using a similar methodology.

Table 1: Comparison with findings in other studies, ordered by publication year

Region	Source	Period of analysis	Dependent variable in regression	Impact of a 1% increase in standards on dependent variable	Standards are associated with share of growth in labour productivity	Standards are associated with share of growth in GDP
France, Germany, Italy, United Kingdom	Blind & Jungmittag (2008)	1990-2001	GDP	0.08%	/	/
France	AFNOR (2009)	1950-2007	GDP	0.12%	27%	24%

Germany	Blind et al (2011)	1961-2006	GDP	0.18%	/	/
United Kingdom	Hogan et al (2015)	1921-2013	Labour productivity	0.11%	37.4%	28.4%
Nordic countries	Menon Economics (2018)	1976-2014	Labour productivity	0.10%	39%	28%
Belgium	Buts et al (2020)	1994-2018	Labour productivity	/	19%	19%
European Union [European standards only]	EY, Menon & Knowence (2021)	1997-2019	GDP	0.06%-0.08%	/	/
Canada	Standards council of Canada (2021)	1981-2019	Labour productivity	0.05%	38%	17%
11 European countries	Blind et al (2022)		GDP	0.02%-0.15%	/	/
This study	Menon Economics (2023)	1970-2019	Labour productivity	0.06%	25%	16%

The majority of empirical studies show similar results. Standards' contribution to GDP growth is estimated to be between 15 percent and 28 percent. The corresponding coefficient from the regression is that a one percentage change in the net stock of standards is associated with an increase in labour productivity and/or output by between 0.05 percent and 0.12 percent.

The most recent studies have slightly lower coefficients than the older ones. While older studies tended to find that standards are associated with 20-30 percent of GDP growth and coefficients of 0.1-0.15, this has been 15-20 percent and 0.05-0.08 in more recent literature. This is not due to a decrease in the role of standards, but rather due to improvements in methodology.

In older studies on standardisation, a *time trend* was used to pick up unincluded variables (institutions, rules and regulations, etc). In more recent studies, *time fixed effects* are used. The main difference is that while *time trends* force those unincluded effects to change equally each year, the *time fixed effects* allow them to vary over time. With time fixed effects, the results are less affected by other, unobservable variables. We therefore consider the results of the newer studies to be more precise.

While using time fixed effects is (relatively) new in analyses of standardisation, it has long been commonplace in the broader field of macroeconomic growth. A large reason this has been absent in standardisation studies is that most studies on standardisation analyse single countries, which tends to make using time-fixed effects unfeasible. Since the use of time-fixed effects in standardisation studies was not commonplace, however, even studies of multiple countries used time trends rather than time-fixed effects, such as the Nordic study of Menon Economics (2018). In appendix A, we show that in a model which uses a time trend rather than time-fixed effects, results are much closer to the older studies, with a coefficient of around 0.1. But as mentioned, we consider that the main model with time fixed effects, which we present the results for in this chapter, results in a better and more robust estimate.

1.4 Standards' contribution to output per year in the future

We have seen how large the historical contribution to GDP of standards has been. In this section, we focus on what one may expect to be the contribution in the future.

The growth in the stock of standards was highest in the period following the New Approach in 1985. Since then, the growth rate has fallen, as shown in Figure 9. The growth rate seems to have stabilised recently, and going forward, it seems likely that the growth rate in the stock of standards is likely to be line with the past decade.

For the past decade from 2013 through 2022, the weighted average growth rate in the stock of standards was approximately 1.7 percent for the analysed countries. Applying the results of the regression above, this means an annual contribution to GDP of approximately 2.6 billion euro associated with standardisation for the group of six countries.[9] This corresponds to an increase of a bit over 100 euro per employee per year in labour productivity growth.

Our regression analyses the countries together in order to provide as good an estimate as possible for the countries combined. This means that we have *one* coefficient for the association between standards and labour productivity for the countries combined. As mentioned in the introduction, all the six countries are highly productive, as well as being small, open economies with long-running standardisation organisations, and it is therefore reasonable to assume that they have a similar coefficient. We therefore consider this regression to be a better estimate for each of these countries than individual regressions on each country would be. We can therefore estimate the contribution of standardisation for each of the six countries using these results.

Figure 12 below shows the yearly future growth in value added associated with standardisation, based on each country's value added in 2021, a growth rate in the net stock of standards of 1.7 percent (in line with the past decade), and the coefficient from our regression analysis. The differences between the countries are therefore driven by the sizes of their economies.

Figure 12: Estimated future annual value added associated with increased standardisation. Real 2021-prices.

A key assumption here is that standardisation work will continue as it has in the past decade. If the stock of standards grows less going forward, then the results will be lower. Likewise, if more focus is put on standardisation, and the stock of standards grows faster, then the results will be higher.

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[9] A 1.7 percent increase in standards would with a coefficient of 0.06 on labour productivity mean a yearly contribution from standards to labour productivity of around 0.1 percent. As the GDP of the six countries was around 2400 billion euro in 2021, that would mean an increase of around 2.4 billion euro.

2 Standards' contribution to international trade

Standards are considered to boost export performance. In a review of the empirical literature, Swann (2010) finds that the general consensus is that standardisation supports export performance by supporting compatibility, reducing transaction costs, and providing a signal of quality to customers.

In surveys of companies, market access has also been highlighted as an important reason for using standards. In a Nordic study (Menon Economics, 2018), survey respondents answered that increased market access is *the foremost* reason for using standards. This was echoed in an EU study (EY, Menon Economics & Knowence, 2021), where around 60 percent of respondents answered that standards contribute to increased market access and reduced barriers to trade.

The effects of standards on trade have also been echoed by the WTO. As Alan Wolff, the Deputy Director-General of the WTO at the time, put it in 2018: "*Without international standards there would be far less international trade, far less global prosperity, far fewer markets for exporters, and far less variety for consumers*".[10]

There is in other words something of a consensus between the literature, companies and institutions that international standards contribute positively to international trade. Nevertheless, there are relatively few estimates on *how much* standards contribute to trade. An ISO research paper on the benefits of international trade states: "*The main reason that the literature on standards and trade remains relatively small, and far from global in its coverage, can be simply stated: lack of data"* (ISO, 2020).

The most influential method in the literature that quantifies the benefits of standardisation on trade is the one introduced by Moenius (2004). Moenius uses a so-called gravity model of trade to estimate how standards contribute to trade flows. The gravity model of trade has been widely applied to explain patterns of international trade during the last 50 years. The gravity model has since been the predominant method for analysing the contribution of standards to trade, in for instance Ramel, Mangelsdorf & Blind (2015), Menon Economics (2009) and Fricke & Chapman (2017).

We utilise the gravity model to investigate the relation between standards and trade. Concretely, we seek to answer the following question: *Does an increase in standards in one industry result in increasing exports from that industry to other countries in the following years?*

2.1 Why should you care about international trade?

Before we go into the model and the contribution of standards to exports, it is worth dwelling briefly on *why* we should care about international trade. There are benefits both for consumers and companies in the countries we are looking at, as well as benefits for developing countries and other trade partners.

- International trade has substantially increased the number of goods and services available to consumers and contributed to making them available at lower prices. Consumers in Northern Europe have access to agricultural goods, technological goods, services and so on that would never have been accessible without international trade.

[10] https://www.wto.org/english/news_e/news18_e/ddgra_28sep18_e.htm

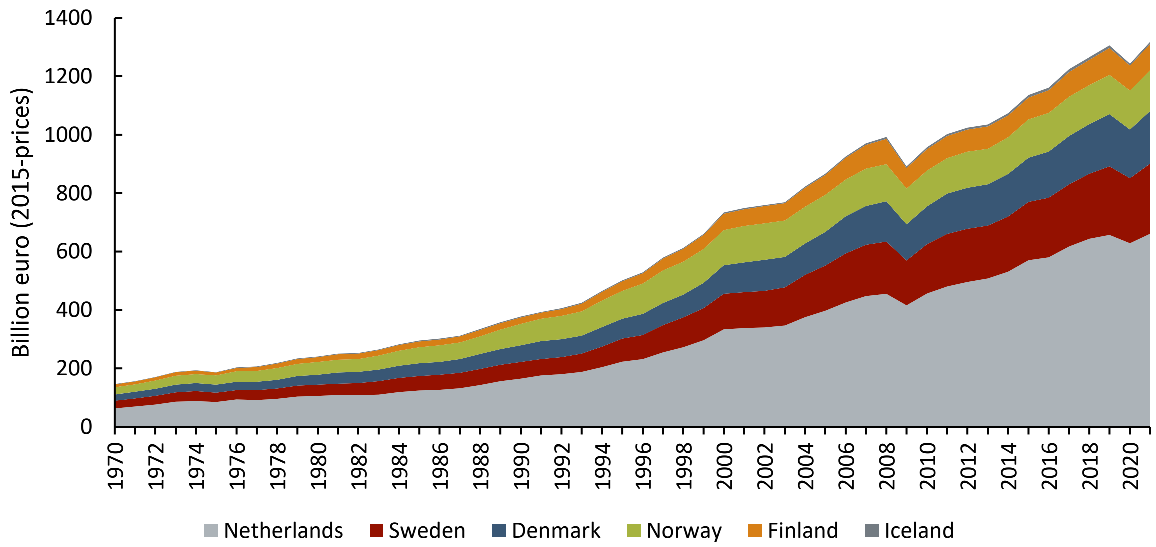
- International trade has also contributed to lifting hundreds of millions of people out of poverty globally.[11] As the World Bank puts it, "*The expansion of international trade has been essential to development and poverty reduction*"[12].

From a social and global perspective, there are in other words clear benefits from international trade. We focus particularly on one aspect of trade here, namely the *exports* from the six countries we are looking at. There is a series of benefits for the six countries from increased exports:

- Exports finance imports. Without high exports, it will be difficult to sustain the high levels of consumption of imported goods and services that northern Europe has enjoyed over time.
- Exports create jobs. In the six countries, between 20 percent and 35 percent of the jobs are sustained by exports.[13]
- Exports contribute to increased productivity. Both micro- and macroeconomic studies have demonstrated that increased exports tend to lead to increased export productivity and thus greater value added for both exporting companies and the economy as a whole.

Over the past 50 years, exports have grown sizably in all six countries.

Figure 13: Exports from the six countries from 1970 to today. Constant 2015-euro at PPP. Source: World Bank



2.2 The trade model

To measure the relation between standards and international trade, we use the gravity model of trade. The gravity model has been referred to as the "workhorse" model of trade and has been applied by thousands of

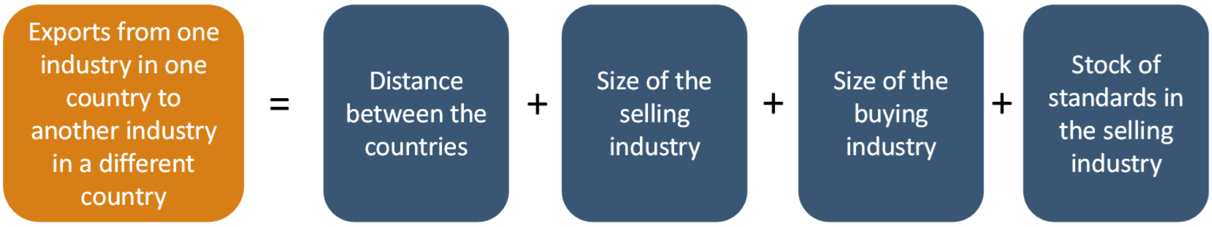
[11] https://www.oecd.org/trade/understanding-the-global-trading-system/why-open-markets-matter/
[12] https://documents1.worldbank.org/curated/en/726971467989468997/pdf/97607-REPLACEMENT-The-Role-of-Trade-in-Ending-Poverty.pdf
[13] https://www.oecd.org/trade/understanding-the-global-trading-system/why-open-markets-matter/

papers.[14] It has previously been used to explain the role of various determinants of trade including GDP, distance, population, patents, and trade agreements.

We are interested in measuring how the net stock of standards affects exports, specifically at the industry level. This means that we want to know how an increase in standards within a particular industry affects the amount of exports from that industry. To conduct this analysis, we use data from the OECD that covers 45 different industries and 66 countries over the period from 1995 to 2018.[15] Our model allows us to examine the exports of each of these 45 industries from 6 countries to 65 other countries.

The model looks at how an increase in *industry-specific* standards affects trade. The variables in the model are shown in the figure below.

Figure 14: Variables in the trade model



The distance between the countries, the size of the exporting and importing industries, and the standards in the exporting industry all play a role in determining exports.

See appendix B for more on the methodology of the gravity model.

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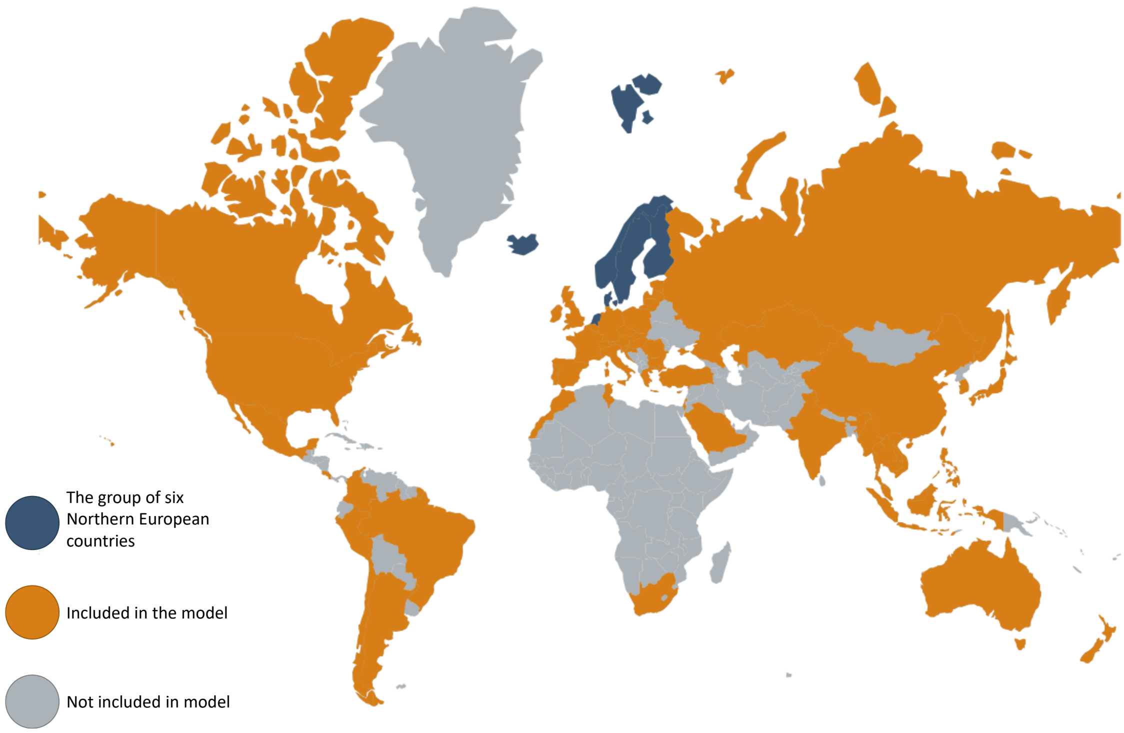
[14] *https://cepr.org/voxeu/columns/gravity-60-celebration-workhorse-model-trade*

[15] *We use data from the OECD's cross-country input output database, which is the data which also forms the basis of the OECD Trade in Values database. See appendix B for a list of included industries.*

Figure 15: Countries included in the trade model



2.2.1 What our model does not include

Our model is designed to answer our research question: *Does an increase in standards in one industry result in increasing exports from that industry to other countries in the following years?*

This is an important part of how standards affect trade, but it is important to note that it is not the full picture of how standards contribute to trade. One shortcoming of the methodology we apply is that it does not allow us to pick up benefits of management standards, such as ISO 9001 and 14001. These management standards are not industry specific, but rather benefit most industries.

Past studies have found that management standards contribute to increased exports. Menon Economics (2009) found that countries with a high certification intensity for ISO 9001 and ISO 14001 tended to export more. Grajek (2004) found similar results. Our model will not pick up on these effects, but instead focuses on the sector-specific benefits.

2.3 The trade results

Our estimation results show that, on average, a 1 percent increase in a sector's net stock of standards is associated with an increase in exports from that sector of a little under 0.09 percent. Since 1995, the net stock of standards has increased on average by approximately 4.4 percent per year, while exports grew from 500 to 1300 billion euro.[16] These results indicate that from 1995 to 2018, standardisation is associated with an increase in exports of around 73 billion euro. Annually, the increase in standards in a sector has been associated with an

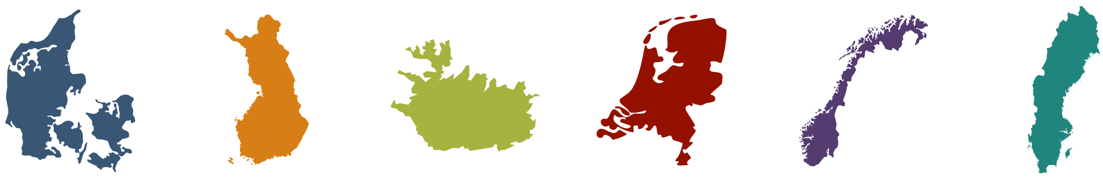
[16] *By World Bank data, cf. Figure 13.*

increase in exports of a little under 3.2 billion euro. This means that our estimates entail that for the period of 1995-2018, around 9 percent of the growth in exports is associated with increased use of standards.

Our regression analysis combines the data from all six countries to provide a more accurate estimate of the association between standards and trade. By doing so, we obtain a single coefficient that reflects the combined impact of standardisation on trade across these countries. This approach is preferable to conducting individual regressions on each country because it enables us to make more precise estimates. We therefore apply this single coefficient to each country to find the country-specific results.

Figure 16 below shows the estimated increase in exports associated with standardisation for each country. This is based on each country's exports in 2021, a growth rate in the net stock of standards of 1.7 percent (in line with the past decade, as discussed in chapter 1.4), and the coefficient from our trade model.[17] The differences between the countries are therefore driven by their total exports.

Figure 16: Estimated future annual increase in exports associated with increased standardisation. Real 2021-prices.



Denmark	Finland	Iceland	Netherlands	Norway	Sweden
2 billion DKK	135 million EUR	1.6 billion ISK	1 billion EUR	2.1 billion NOK	3.6 billion SEK
(270 million EUR)		(10 million EUR)		(210 million EUR)	(360 million EUR)

= 2 billion EUR

One important assumption underlying these estimates is that standardisation efforts will continue at a similar pace to the past decade. If the rate of growth in the stock of standards slows down in the future, the results of our analysis will likely be lower than expected. Conversely, if there is increased attention given to standardisation and the stock of standards grows at a faster rate, then the results will be higher.

[17] *See Appendix B for the calculations.*

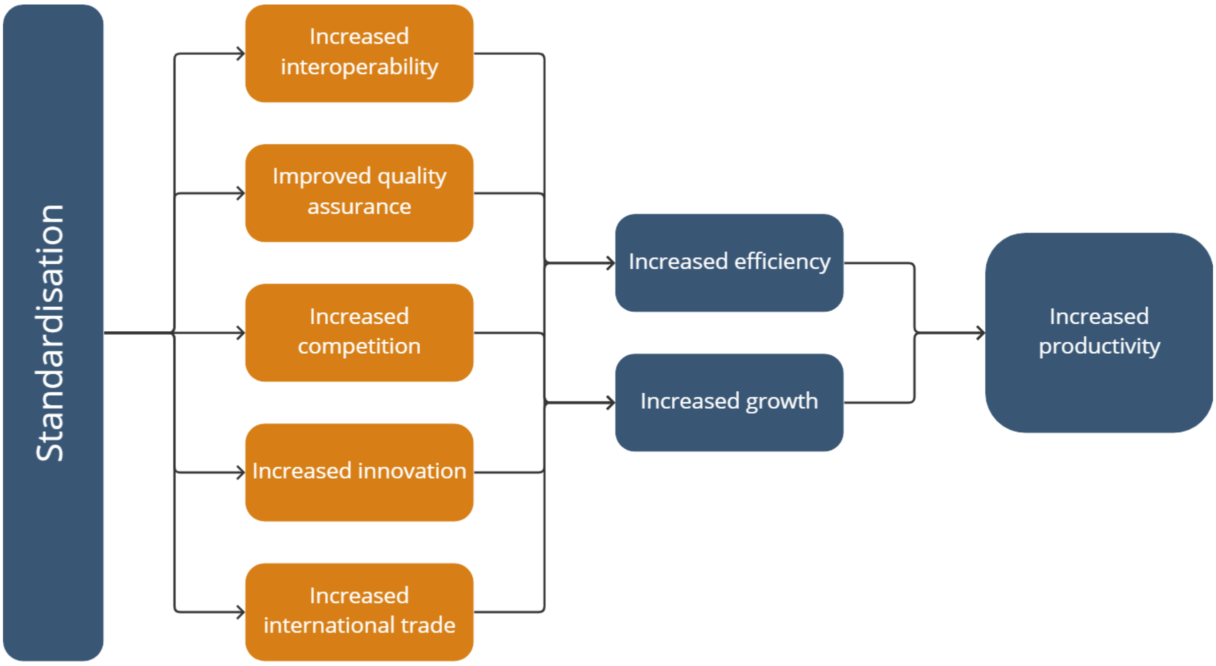
3 How does standardisation affect productivity?

In this chapter, we explore the various mechanisms in which standardisation affects productivity, including how it can increase competition and interoperability, improve the quality of output, and facilitate trade and innovation. We also discuss the potential drawbacks of standardisation.

In the productivity chapter, we conducted a macroeconomic analysis to estimate the magnitude of the productivity benefits associated with standardisation. In this chapter, we review previous research, surveys and economic theory to explore *how* standards can affect productivity.

These effects come through several mechanisms. As outlined in chapter 1, we consider five primary mechanisms through which standards contribute to productivity: Competition, interoperability, quality assurance, innovation, and trade. It is worth noting that these mechanisms do not operate entirely independently of each other; for example, as discussed in subchapter 3.4, improved quality assurance may also affect innovation. The illustration and chapter structure should therefore not be seen as a comprehensive representation of all causal relationships, but rather a broad overview of how standardisation contributes to productivity.

Figure 17: The mechanisms through which standards affect productivity



These factors are the most important contributors to increased productivity, but the list is not exhaustive. These factors are used in most studies, but we have aggregated them slightly and used a less technical language in order to make the effects more clear. Some factors, such as increased interoperability and improved quality assurance, are included in almost all studies. These are highlighted as important factors in all the analyses shown in Table 1, which all investigate how standards can affect productivity.

One commonly used factor which we have not included in the figure is "*Reduced variety of intermediate goods".* The general point here is that standards may reduce the variety of intermediate goods, which enables the exploitation of economies of scale without reducing the choice of consumers. A chief benefit here is an increase in competition, since standards contribute to competition within a category of intermediate goods, rather than many proprietary solutions. We find that the title *reduced variety of intermediate goods* is quite technical, and have therefore opted for the term “Increased competition”.

Another factor often used but not included in the figure is “*Distribution of technical information”*. This refers to the idea that standards make product information and descriptions accessible, in turn diffusing technological progress to a wider group of companies. This, in turn, increases competition and creates a common base from which firms can innovate. In other words, it contributes to increased competition and increased innovation, and we have therefore used those categories instead, which are more tangible for a general reader.

In this section we review economic theory, literature and survey data to provide evidence for how the various factors affect productivity. We find that the surveys are of particular value, as they provide insights into what companies deem to be the primary advantages of standards. We focus mainly on three recent studies:

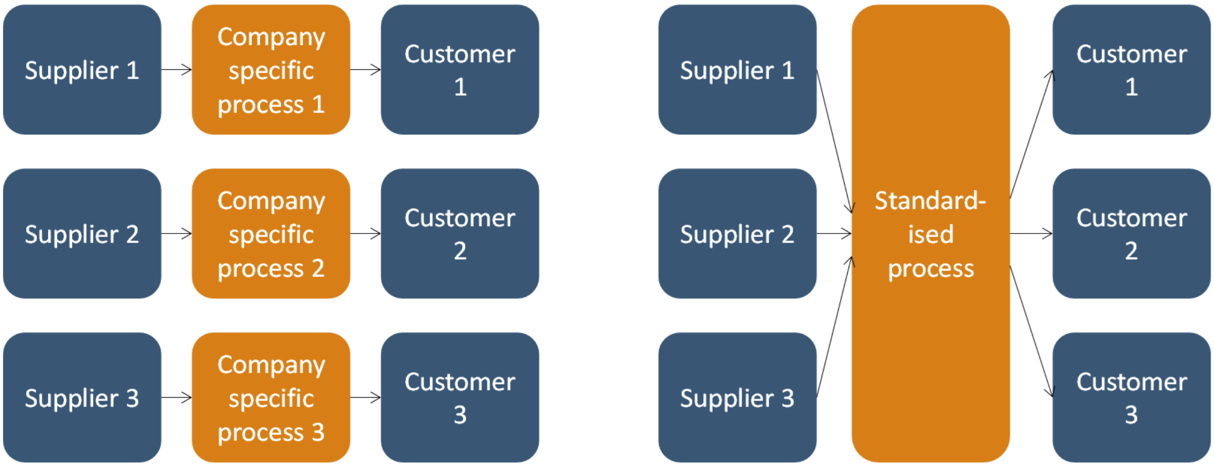
- The EU study “Functions and Effects of European standards” analysed how standards contribute to the goals of the European Commission. It contained a survey of 639 European companies, with a particular focus on SMEs. (EY, Menon Economics & Knowence, 2021)
- The Nordic study of 2018 analysed how standards affect economic development in the Nordic countries. It included a survey of 1 179 companies from eight sectors, as well as case studies. (Menon Economics, 2018)
- The Belgian study of 2021 examined how standards have contributed to the economic development of Belgium, with a survey of 663 companies from the private sector and public institutions headquartered in Belgium. (Buts, Dooms, Willems, Droogenbroeck, & Soyeur, 2022)

Menon Economics was involved in the first two studies, but not in the Belgian study.

3.1 Increased interoperability

When interviewing those who perform standardisation work, *interoperability* is the perhaps most commonly used word to explain the direct benefits of standardisation. By interoperability, we mean the ability of different systems, devices, processes, or applications to work together in a coordinated and seamless manner. Indeed, this is the core aspect of standardisation: Rather than having multiple different systems and processes, the standardisation process establishes a consensus everyone can agree upon. The figure below illustrates an example of this.

Figure 18: Illustration of the difference between separate, unstandardised value chains (left) and standardised value chains (right)



In the example on the left, there are three different companies, each with their own unique company process. There are therefore three different, competing value chains that solve tasks in their own way. On the other hand, the example on the right shows a scenario where the main task has been standardised. This means that all suppliers can deliver their products to the main process, and all customers actors can use what is produced by the standardised process. Standardisation transforms the competing value chains into a single value chain with increased interoperability.

In the EU study, almost 70 percent of respondents believed that standards make a large or very large contribution towards increasing interoperability and compatibility in their firms. All sectors surveyed considered that standards contributed to interoperability, although what this meant varied across different sectors. In particular, manufacturing, ICT and logistics firms placed great importance on interoperability. In the text box below, we provide some insight on how interoperability differs in these three industries.

Interoperability in different industries

Manufacturing: By using a common set of standards, manufacturers can ensure that their products meet the same technical requirements and specifications, regardless of where the products come from. This enables them to purchase goods from a wider range of suppliers and avoid being locked into suppliers with proprietary technology. In the Nordic study (Menon Economics, 2018), 97 percent of manufacturing firms reported using standards. They report many reasons for doing so, but two main categories of the responses are:

1. Standards ensure that the input goods we buy work with our processes
2. Standards ensure that the products we sell meet our customers' expectations

ICT: Standards form a backbone of the IT industry, which involves transmitting, storing, and retrieving data using computers and telecommunication equipment. For data to be shared efficiently, every device must be capable of sending and receiving information using a standardised format or software language. These standards cover a wide range of topics, from hardware interfaces and data formats to network protocols and software languages. Without standardised formats and protocols, communication between devices would be substantially less efficient.

Logistics: Transporting goods requires goods to be packaged, stored and transferred between varying modes of transportation. The use of standardised containers allows for easy stacking and movement of containers, ensuring seamless transfer between ships, trains and trucks. Standards, such as GS1 standards, are also important for enabling businesses to effectively track products throughout the supply chain, from the point of manufacture to the point of sale. The warehouses, trains, trucks, ships and all interoperate, creating a substantially more effective logistical chain.

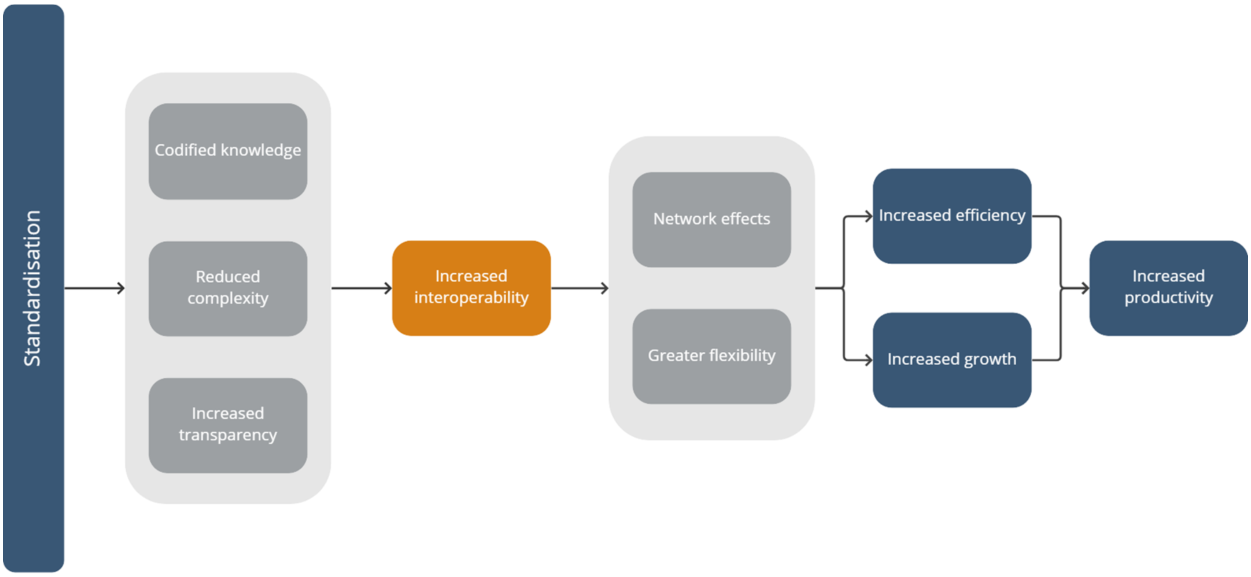
3.1.1 How does improved interoperability contribute to productivity?

When systems, products, and processes are able to interact in a seamless and consistent manner, the value chain is simplified and streamlined, resulting in greater efficiency and productivity. When suppliers are interoperable, producers can easily switch from one supplier to another without having to readjust the entire production line. This allows companies to take advantage of the best prices, services, and resources available, resulting in improved cost efficiency and thus productivity. Additionally, improved interoperability can lead to faster time to market, enabling companies to rapidly capitalize on opportunities in the market.

Interoperability is also an important driver of network effects, as highlighted by for example Hogan (2015). Network effects occur when the use of a product or service becomes more valuable as more people use it. Standards that increase interoperability drastically increase the number of actors who can use software, products, marketplaces and services. This again allows for vast economies of scale, driving productivity and allowing for larger production for the same level of input.

The figure below illustrates the points presented in this chapter.

Figure 19: Illustration of how standardisation contributes to increased interoperability, and how this again contributes to increased productivity



Going forward, there are strong arguments interoperability may become an even larger driver of productivity. This may be particularly clear in fields at the intersection of logistics and information technology, such as Intelligent Transportation Systems (ITS). For instance, with self-driving cars, it is crucial that all the different components, such as the onboard sensors, navigation systems, and communication devices, can exchange information in a standardised way. Doing so enables the vehicle to react to shifting road conditions and other vehicles on the road, thus improving safety and reducing congestion. Similarly, in a smart traffic management system, standardised communication protocols allow traffic lights, sensors, and other components to interact seamlessly, leading to better traffic flow and fewer delays.

3.2 Improved quality assurance

Standardisation ensures quality assurance by defining technical requirements and specifications for products, services, and processes. Standardisation promotes best practices and procedures that have been proven to work effectively, reducing the risk of errors or defects. This leads to consistent quality levels, regardless of where the products are produced. Standardisation also provides a framework for testing, certification, and accreditation, which helps to validate the quality of products, services, or processes. The use of standardised methods ensures that products consistently meet the same quality levels, increasing customer confidence in the product or service and leading to increased customer satisfaction and loyalty. Overall, standardisation plays a significant role in ensuring quality assurance by establishing consistent and reliable quality levels across different products, services, and processes.

In the Belgian survey conducted by Buts et al. (2022), 70.3 percent of the participating firms listed *improved product/service quality* as an important reason for using standards, making it the most universally important reason in the survey. These results were also found to be consistent across firm sizes and most sectors. There are two main factors that decide the effect of standards on quality assurance: whether the standard manages to force the exit of low-quality firms, and whether it also results in the exclusion of some high-quality firms.

Forcing out low-quality products: When introducing a new quality standard, firms that are unable to comply with the requirements are forced to exit the market. As a result, the average quality of the product or process in question will increase, even if the market actors' quality expectations are indifferent to the introduction of the standard.

Lower quality incentives for high-quality firms: The effect described above can be dampened by the exclusion of high-quality, low-productivity firms. When a quality standard is introduced, competition among firms who operate above the quality threshold of the standard will increase (partially due to low-quality firms being excluded, and others adapting to fit the new threshold). This heightens the benefits of price competition, as the relative competitive advantage of high-quality firms is reduced. In other words: It becomes more profitable to produce medium-quality products just above the quality threshold, rather than producing high-quality products as before.

When investigating these relationships with empirical data, Disdier et al. (2020) found that enforcement of quality standards leads to a rise in average quality of traded products, and the exit of less productive firms. While an overall positive relationship between quality standards and average quality is indicated, just a limited number of these positive relationships were found to be significant on a sector level.

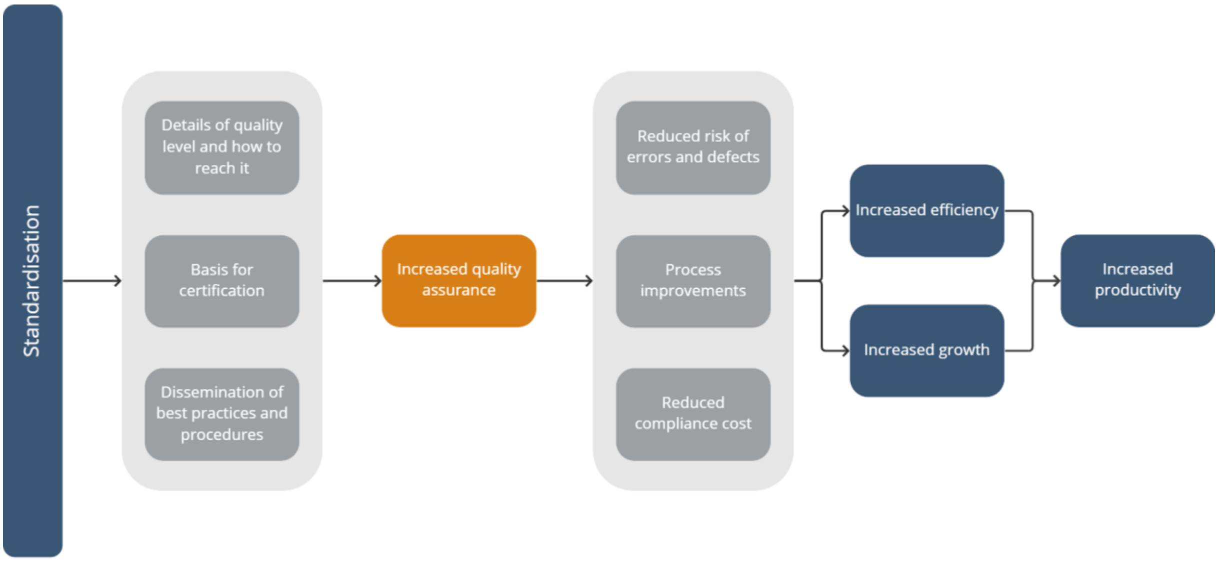
3.2.1 Why does increased quality assurance improve productivity?

By defining clear guidelines, definitions and procedures, standards can ensure predictable qualities of products and processes. This predictability may be beneficial for the firm that applies the standards, as the firm can take priorities set by the standards as given, rather than spending resources on investigating alternatives that the standard now has ruled out for them. In addition, increased quality thresholds as a result of new standards may force firms to increase their productivity in order to obtain higher quality products with the same inputs as before.

When producers know their suppliers adhere to a standard, they can also be confident in the quality and properties of their product. This will again reduce the need for additional quality controls and risk of production errors, which otherwise would be costly to the firm's productivity. This is also supported in literature; in the Nordic study by Menon Economics (2018), 65 percent of responding firms pointed out that standards reduced the risk of manufacturing errors within the company. The same share of respondents also indicated that standards raised the quality of subcontractors.

The figure below illustrates the points presented in this chapter.

Figure 20: Illustration of how standardisation contributes to increased quality assurance, and how this again contributes to increased productivity



3.3 Increased competition

Standardisation promotes competition by creating a level playing field for businesses of all sizes and in all sectors, and allowing new companies to enter the market. There are three main factors driving standards' benefits to competition: Reduced variety of intermediate goods, dissemination of technical information at a low cost, and increased trust in newcomers to the market.

Reduced variety of intermediate goods and increased transparency: Standards can lead to a reduction in the variety of intermediate products, thereby allowing companies to compete more transparently. In a survey of UK firms by Hogan et al. (2015), 63 percent of firms cited that standards had homogenised products to the extent that price competition had increased. Interestingly, an even larger amount of 87 percent of firms found that standards enabled the differentiation of products according to other attributes such as product quality, delivery and customer service. The standards thereby formed a common basis from which firms could compete more transparently.

Dissemination of technical information makes entering a market easier: Standards make product information and descriptions accessible at a low cost. This allows smaller actors to enter the market without having a large R&D department. Furthermore, standardisation heavily benefits *modularisation*, whereby many smaller actors can deliver standardised products. This means that companies can buy products from a wide range of suppliers delivering standardised goods, rather than relying on one or a few large suppliers delivering proprietary products. This both promotes increased competition between suppliers and makes it easier for new actors to enter the market by delivering standardised products.

Increased trust in newcomers to the market: Earning trust can be difficult for a newcomer to a market. In the EU study, 67 percent of surveyed companies reported that standards "help create trust and confidence between companies and their customers". Similarly, 54 percent stated that standards help facilitate the formation of new business partnerships. This signals that standards make it easier to trust new suppliers, and form new relationships.

3.3.1 How does increased competition affect productivity?

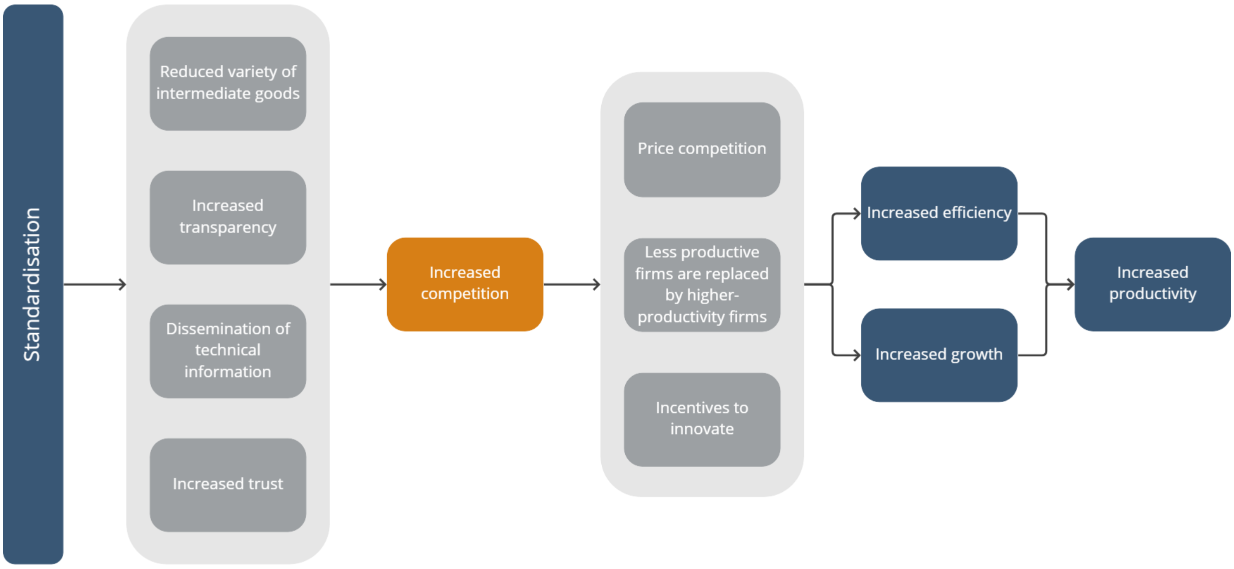
Increased competition is widely recognized as a key driver of productivity growth. In a review of evidence, Holmes (2010) notes that *nearly all the studies found that increases in competition led to increases in productivity*. Competition induces firms to become more efficient and innovative, leading to improvements in productivity. In a summary of the evidence, the UK's competition and market authority[18] summarised the reasons for this in three points:

- Competition disciplines firms, placing pressure on the managers to become more efficient.
- Competition ensures that more productive firms increase their market share at the expense of the less productive. These low-productivity firms may then exit the market, to be replaced by higher-productivity firms.
- Competition drives firms to innovate, coming up with new products and processes which can lead to jumps in efficiency.

Summarised, competition forces firms to adopt more efficient production methods and to reduce costs to remain competitive. The pressure to optimise production processes can lead to the elimination of redundant processes, the introduction of new technologies, and the adoption of more effective business practices. As a result, increased competition drives firms to become more efficient, reducing waste and increasing productivity.

The figure below illustrates the points in this chapter.

Figure 21: Illustration of how standardisation contributes to increased competition, and how this again contributes to increased productivity



3.4 Increased innovation

Studies suggest that standards generally have a positive impact on innovation, although the specific results can depend on the organisation in question as well as the characteristics of the market in which they operate (ISO, 2022). The Nordic study (Menon Economics, 2018) found that companies rarely viewed standards as a hindrance

[18] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/909846/Productivity_and_competition_report__.pdf

to developing innovative technology. The subsequent EU study (EY, Menon Economics & Knowence, 2021) used data from the Community Innovation Survey (CIS) and analysed how standards may affect innovation. They found that firms in sectors with more standards have more innovations that are world leading or new to the market, but fewer innovations that are new only to the firm. The study considered that this supports two hypotheses: First, that standards create a common platform, so firms do not need to perform firm level innovations already known to others. Second, that when the standards push more firms up to the frontier, the number of firms which can make new innovations increases, which again leads to more innovation.

The notion that standards drive innovation is shared by the EU Commission. The commission states this as follows: "*Standards help researchers and innovators bring their innovation closer to the market and spread technological advances by establishing uniform criteria and by developing methods, practices and procedures which are publicly available in a formal document".*[19]

The standards development process itself is also believed to promote innovation. Cebr (2015) upholds that by bringing together experts from industry, professional institutions, trade associations, certification bodies, testing and inspection bodies, research organisations, consumer interest organisations, educational bodies and government departments, the process of developing standards facilitates market-driven innovation and enables creation of user-oriented solutions. However, in sectors with rapid technological advances (e.g. Life Sciences, Energy and IT) development of standards is more often found to lag behind technological development, making standards a constraint rather than a facilitator for technological innovation. To ensure successful innovation, it is therefore important that the process of developing standards is effective enough to reduce the risk of constraining innovation, while also being thorough enough to create consensus amongst stakeholders (ibid).

Based on ISO's literature review (2022), we can summarise the ways in which standardisation affects innovation into five main categories:

- Dissemination of technical information
- Reduced variety of intermediate goods
- Quality assurance
- Compatibility
- Insurance

Perhaps unsurprisingly, the factors affecting innovation are similar to those affecting productivity. In this subchapter, we focus only on how these factors affect innovation.

There are elements of each of these areas that can either encourage or impede innovation, and it is the net effect of the various elements that will determine how standards will impact innovation in a given firm or sector. In the subsequent paragraphs, we will explore the potential positive and negative influences of standardisation in each category.

Dissemination of technical information

Standards allow dissemination and streamlining of knowledge and can help organisations access knowledge that would otherwise be unavailable, thus creating a more conducive environment for innovation. It also provides a

[19] *EUR-Lex - 32023H0498 - EN - EUR-Lex (europa.eu)*

shared knowledge base across companies and sectors, which again can make collaboration on innovation more efficient (ISO, 2022).

However, there are potential drawbacks to this form of information sharing. Organisations with fewer resources may experience high costs of screening standards, and there is a risk of unintentional knowledge spillovers to competitors that may reduce competitive advantage (ISO, 2022).

Reduced variety of intermediate goods

The implementation of standards will decrease the variety of products in the market. This allows for more efficient production through economies of scale. For emerging industries and technologies, fewer variations of a product may reduce the time and resources needed to reach a critical mass (ISO, 2022), thus avoiding the so-called *Valley of Death*[20].

The lack of product variation may also hinder radical innovation, as the risk of developing new products may be higher than investing in incremental innovations of already dominant products and processes. For example, by analysing patents filed from 1978 to 2013, Brem et al. (2016) find that patent classes which have had a dominant design for more than seven years have a very low patenting frequency, which can be seen as a proxy for product innovation. Furthermore, less variety limits choice, and may unintentionally prevent the emergence of products and technologies that could be better suited to meeting the needs of companies, sectors, and consumers in the future. Lastly, limiting product variation may lead to market concentration, where a large portion of the market is dominated by a small number of companies (ISO, 2022).

Quality assurance

The existing literature about quality standards and their effect on innovation is conflicting. Manders et al. (2016) conducted a literature review of 29 studies of the ISO 9001 standard, which has been adopted by over one million organisations in 187 countries. The majority of the literature suggests no impact of the standard on product innovation, but that the overall effects were unclear. They theorised that the conflicting evidence might be due to a lack of focus on the extent to which companies adopted the standard, rather than simply using ISO 9001 certification as a binary variable. Thus, the differences in the degree of adoption of ISO 9001 may explain the differences in innovation benefits between the companies.

One prominent theory on how quality standards affect innovations is that they ensure a minimum quality of products, and knowing that suppliers and collaborators adhere to certain standards can reduce the resources spent on additional coordination and quality assurance. This allows resources to rather be fuelled into product improvement and innovation (ISO, 2022). In addition, quality standards provide a benchmark for innovation and ensure that products are of adequate quality in order to propel further innovation. As a result, organizations strive to meet or exceed these quality standards and achieve greater success in their product development.

However, quality standards may have adverse effects on adopting new innovations and time to market for new products, as found by Terziovski and Guerrero (2014). This may increase the investment costs of innovation, and therefore create a market barrier for new products. This theory is further supported by the Nordic study (Menon

[20] *The "Valley of Death" is a term describing the initial phase of new ventures, where operations have begun but sufficient revenue is yet to be generated. During this time, there is a heightened risk of failure due to a lack of financial liquidity, which can lead to a premature end of the business, industry, or technology.*

Economics, 2018) where only 26 percent of responding companies agreed with the statement "Standards reduce time to market for new products".

Compatibility

By ensuring compatibility across sectors and technologies, standards may promote positive network externalities and increase the variety of system products available. However, defining compatibility standards, especially in technology, may hinder radical technological advancement and thus foster lock-in into older technologies. Furthermore, it is possible that the implementation of such standards could lead to the emergence of a single provider of system-compatible products, creating monopolistic markets (ISO, 2022).

Insurance

Foucart and Li (2021) argue that technology standards can be used as an "insurance" to mitigate the risks associated with radical innovation, especially for those further away from the technological frontier. While this insurance theoretically provides a safety net for radical innovation, the researchers find that it instead significantly enables a firm's incremental innovation, while reducing the incentives for companies to invest in radical innovation.

Factors that influence the effect of standardisation on innovation

For standards to guide the direction of research and innovation, they rely on effective, efficient implementation and proper market surveillance and regulation. Hawkins et al. (2017) find that standards have a greater impact on innovation efficiency in uncertain markets than in mature markets. This is because new and uncertain markets often lack the necessary legitimacy to provide the resource mobilization and desirability that is essential for the successful introduction of new technologies and innovations. Standards can address this gap in two ways: Firstly, they provide guidance to reduce uncertainty and diffuse necessary information for innovation, as well as to increase buyers' acceptance and trust in new technologies, thereby increasing demand in the market. Secondly, standardisation can solve conflicts between different stakeholders and technologies, allowing them to coexist and receive more value and innovation opportunities in the market. However, in more mature markets, standards may be used by market leaders to restrict competition and inhibit new entrants and technologies, thus preventing innovation. When patents and standards are combined, they enhance these innovation-inhibiting effects by further cementing market monopolies. Therefore, regulation and legislation has been found to be more effective than standards in promoting innovation efficiency in mature markets.

3.4.1 How does increased innovation affect productivity?

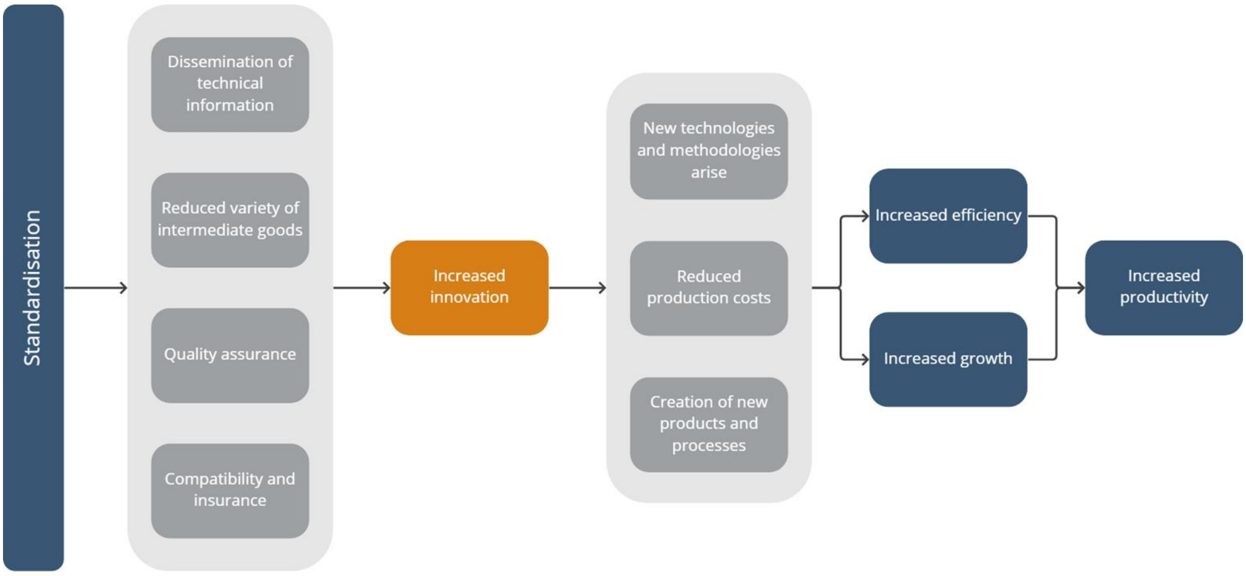
Ever since the Austrian economist Joseph Schumpeter's seminal work in the 1930s, it has been recognized that innovation in products and processes is a prerequisite for long term economic growth. Innovation is perhaps the core driver of technological growth and productivity.

A review by Mohnen & Hall (2013) finds that several studies on the relationship between innovation and productivity conclude that an increase in innovative sales per employee by 10 percent results in a rise in labour productivity of around 2.5 percent. The positive effects are consistent across all types of innovations considered (product, process, organizational or marketing). The ways in which innovation affects productivity can be summarized in the following bullet points:

- **Product innovations** can replace old products that require more inputs, thus increasing the productivity for each unit of input. New products may also create new sources of demand, which can give rise to economies of scale in production.
- **Process innovations** are often introduced to reduce production costs. This often happens through saving costly inputs (such as labour). The reduction in unit costs may translate into increased production or price decreases. The same effects apply for organizational and marketing innovation.

The figure below illustrates the points in this chapter.

Figure 22: Illustration of how standardisation contributes to increased innovation, and how this again contributes to increased productivity



3.5 Other effects

Standards serve a variety of purposes, many of which are unrelated to increasing productivity. Examples of this include promoting health and safety, consumer protection and environmental protection. In the short term, these objectives can lead to more elaborate and expensive production processes, thus reducing productivity. Nevertheless, this adverse impact on productivity is not as apparent in a broader, societal perspective; protecting worker health, sustainability etc. is important in itself to ensure productivity at a long-term macro level. Moreover, standards may be the least productivity-reducing method of promoting these goals.

In a study of the use of standards in regulation, Menon Economics (2022) finds that regulation made with reference to standards is often less rigorous than regulation made without reference to standards. Without reference to standards, the regulators would have to regulate more directly. This often creates more barriers and inefficiencies than referring to standards, which tend to be more closely connected with the industry.

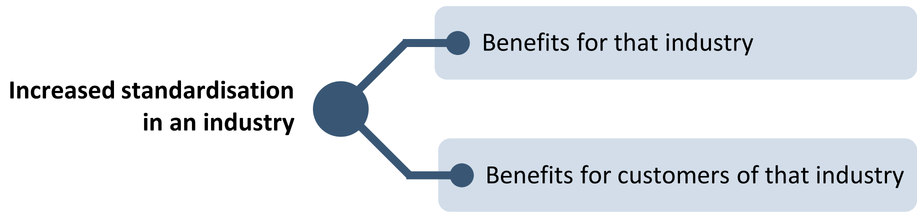
4 Who reaps the productivity benefits of standardisation?

In chapter 1, we quantified how much of the increase in productivity is associated with standardisation. In this section, we explore who benefits from this increased productivity. Specifically, we examine which firms in the value chain become more productive as a result of standardisation.

Standardisation brings a wide range of benefits to the firms that apply the standards. However, it also affects their customers. When customers purchase standardized products and services, it simplifies their processes. This is shown for instance in tenders[21], where standards are frequently used. By standardising their products and services, firms simplify the buying process for their customers and ensure the quality of their products. Additionally, this ensures that the products and services they purchase are interoperable with other systems, providing a level of quality assurance. In other words, if a seller standardizes, it makes things easier for the buyer.

We would therefore hypothesise that *both* firms that standardise *and* customers of those firms see productivity gains. This is illustrated in the figure below.

Figure 23: Both the industry itself and its customers benefit from standardisation.



4.1 How standards provide productivity benefits in select industries

The mechanisms presented in chapter 3 affect both those who apply the standards and their customers. Just as increased quality is important for a firm, it can also contribute to substantial benefits for the customers. The specific mechanisms that benefit the standard-applying firms and their customers varies between industries. To illustrate this, we examine the textile industry and transportation services as two examples.

4.1.1 Productivity benefits of textile industry standards

The textile and clothing industry has many standards related to the manufacturing process of textiles, and for ensuring that the quality of the textiles is sufficiently good. One such example is ISO 15797, which specifies methods for evaluating industrial washing of workwear, or ISO 105, which specifies tests for colour fastness. The key factor in the standards for the textile and clothing industry is in other words *quality assurance.*

Who benefits from increased quality assurance in the textiles industry? Based on our hypothesis, a large beneficiary would be the customers of the textile industry. Three of the largest customers of the textile industry are the construction industry, health care services, and furniture manufacturing.[22]

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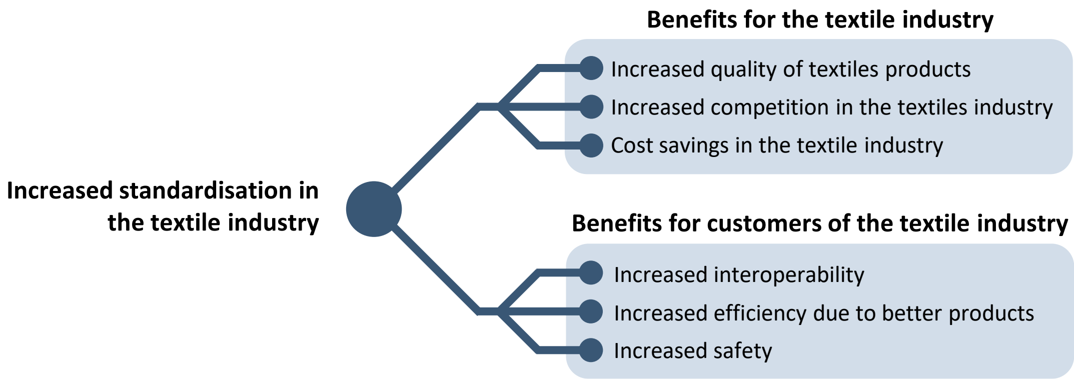
[21] See EY, Menon & Knowence (2021) for a detailed examination of how standards are used in tenders.
[22] For the six countries we are looking at, according to the OECD cross-country input-output matrices. These are three of the four largest customers, with the trade (retail/wholesale) industry being the fourth.

Protective clothing is important for the first two industries – the construction industry and health and care services. For the construction industry, standards such as ISO 11611 are relevant, which sets out the minimum safety requirements for welding work. For the health care sector, standards such as EN 14683, which specifies the construction, design, performance, and testing requirements for medical masks are important. These standards help minimize the risks associated with using these products and reduce the likelihood of injuries and infections.

For the furniture manufacturers, the quality standards ensure that the textiles are easier to integrate into their processes. Knowing the colour fastness and the quality of the textiles simplifies the process of changing suppliers and increases interoperability in the furniture industry.

Figure 24: Illustration of possible benefits of textile industry standards



4.1.2 Productivity benefits of standards for transportation services

As discussed in chapter 2.1, increased international trade has been a significant driver of economic growth and prosperity. Standardisation has brought about many benefits for international trade, particularly in transportation services, with the standardized freight container being a crucial example.

Without a standardised method of producing freight containers, the market would be flooded with various container types, varying in size, quality, and weight capacity. This would make it challenging for companies like car manufacturers to estimate transportation costs associated with each container type, and shipping companies would struggle to efficiently load and unload the different container sizes.

To address this issue, ISO's technical committee published the first standard related to freight containers in 1961, and since then, ISO/TC 104 "Freight containers" has standardized almost every aspect of freight containers. This standardization has contributed to significant economic changes, with transportation costs significantly lower than they would have been otherwise (Levinson, 2015).

While shipping firms and other transportation actors have benefited somewhat from this standardization, the majority of the benefits have been reaped by other firms and consumers.

4.2 Modelling standards contributions in the value chain

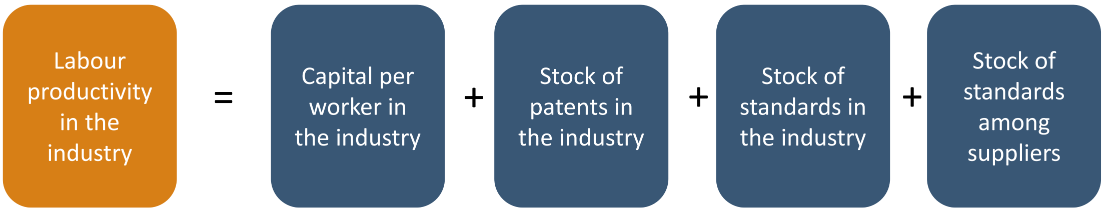
To analyse the value chain benefits of standardisation, we perform an analysis at the industry level. We perform a regression on labour productivity similar to the one in chapter 1, but with two key differences:

- Instead of looking at the countries as a whole, we run the model per industry.
- We include the stock of standards *among suppliers* as a factor. We estimate this based on the number of standards used in the industries that supply the main industry, weighted by how much they supply.

As an example of the standards among suppliers, take the textile industry again. One of the largest suppliers of the textiles industry is the chemical industry, which accounts for around 20 percent of the input to the textiles industry.[23] If the stock of chemicals standards increases by 10, that contributes to an increase of 2 in the textiles industry's upstream stock of standards.

The structure of the value chain model is shown in the figure below, and explained in more detail in appendix C.

Figure 25: Illustration of the value chain model



We perform this analysis for 25 industries, for the six countries, from 1970 to 2019.

4.3 The value chain results

The table below shows the value chain results.

Table 2: Results of the key coefficients in the value chain regression

	Capital per worker in the industry	Stock of patents in the industry	Stock of standards in the industry	Stock of standards among suppliers
Coefficient	0.611***	0.0347***	0.056***	0.087***
(t-statistic)	(23.2)	(4.32)	(8.45)	(8.44)

**** p < 0.01, ** p < 0.05, * p < 0.1*

The table shows that both the stock of standards in the industry and the stock of standards among suppliers have positive and statistically significant coefficients (0.056 and 0.087, respectively). This supports the hypothesis that standardisation benefits both those who standardise and their customers.

It is worth nothing that the coefficient for supplier standards is higher than for in-industry standards, suggesting that the benefits for customers of those who standardise may be greater than for the firms that standardise. This has important policy implications, as it means that the largest benefits are realised not by the firms that are undertaking the cost of standardising, but rather by their customers. Economists call this a positive externality.

[23] *Source: OECD's input-output matrix, calculated for the six countries*

It indicates that the social benefits of standardising are higher than those internalised by those making the decision about whether to standardise.

4.4 Policy implications and future research

In this section we briefly outline the significance of these positive externalities, and what the policy implications are. Positive externalities occur when a firm's economic actions increase the well-being of others without receiving compensation for it. Economic theory suggests that firms only internalise their private costs and benefits and do not sufficiently consider the benefits for others when making their decisions. As a result, the focus on private returns rather than social returns leads to firms producing too few goods and services where there are positive externalities.

The findings of this chapter reveal that the decision to standardise creates gains outside of the standardising firms. Since the ones making the decision to standardise are not compensated for all the gains, it is likely that we standardise less than what is optimal from a social perspective, i.e., that society would benefit if firms dedicated even more resources to standardization.

The issue of incentivising actions that generate positive externalities is often raised in relation to research and development (R&D), since the R&D undertakings of individual firms have positive effects beyond those enjoyed by the firm itself. For this reason, almost all OECD countries provide R&D subsidies in order to incentivise more R&D by companies.[24] Similar arguments as for R&D can be made for incentivising further standardization.

Governments have many tools available to incentivise actions with positive externalities. Examining which tools may be most effective, and how large the incentives should be, is an interesting topic for future research.

[24] https://www.oecd.org/sti/rd-tax-stats-database.pdf

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Appendix A: Methodology of the productivity analysis

The methodology for analysing the economic benefits of standardisation largely builds on models popularised by Blind (2000). There have been many subsequent studies using this methodology, which is based on a Cobb-Douglas function. These analyses either focus on how standards contribute to *labour productivity* or *output.* In this report, our main results are on *Labour productivity,* while we also run the analysis on output as a robustness check (later in this appendix). The Cobb-Douglas function for labour productivity is in the shape of:

$$Labour\ productivity_{it} = F(Capital\ per\ worker, Net\ stock\ of\ standards, \quad Patents, Recession)$$

where $Labour\ productivity_{it}$ is the labour productivity in country *i* in year *t.* The capital per worker is the capital stock in the country. The net stock of standards is the number of active standards per year, while *Patents* is a proxy of the knowledge stock. We calculate the patent stock as the sum of all patents granted by the European Patent Office, with a depreciation rate of 15 percent. Recession is a dummy variable.

A key assumption in Cobb-Douglas form analyses is that the variables are *cointegrated*. When variables are cointegrated, they move together in the long term, even if they may deviate in the short term. On the other hand, if the variables are *not* cointegrated, they have no long-term relation, and Cobb-Douglas functions may provide spurious results.

Empirical cointegration test

To test for cointegration, we use two tests from two studies, the ones of (Westerlund, 2005) and (Pedroni, 2004), using the Stata package xtcoinntest. The Pedroni tests perform three different subtests, which all have the null-hypothesis that the panels (countries) are not cointegrated, and the alternative hypothesis that *all* panels are cointegrated. The Westerlund test tests both with the alternative hypothesis that *some* panels are cointegrated, and that *all* panels are cointegrated.

The results of the tests are presented below.

Table 3: Cointegration results

Source	Test type	T-statistic (p-value)
Pedroni	Modified Phillips-Perron	-1.9643** (0.0247)
	Phillips-Perron	-1.3881* (0.0826)
	Augmented Dickey Fuller	-1.0425 (0.1486)
Westerlund	Alternative hypothesis: Some panels cointegrated	-1.9169** (0.0276)
	Alternative hypothesis: All panels cointegrated	-1.316* (0.0941)

** p<0.05, *p<0.1

The five tests deliver ambiguous results. Of the Pedroni tests, one suggests cointegration at the 5 percent level, one at the 10 percent level, and one not at either significance level. Meanwhile, the Westerlund test suggests at the 5 percent level that at least some panels are cointegrated, and at the 10 percent level that they all are cointegrated.

This is similar to what previous studies have found regarding cointegration for this type of models. For instance, Blind et al. (2022) also found that the Modified Phillips Perron and Phillips-Perron tests suggested cointegration at the 5 percent and 10 percent levels (with some variance between model setups), but that the Augmented Dickey-Fuller method did not suggest cointegration at any significance level.

While there is some ambiguity, we find that these results *mostly* indicate cointegration, and therefore proceed with our main model. Since there is some uncertainty, however, we also include a model at the first-difference level as a robustness test. This means that we analyse how a *change* in the explanatory variables affects the *change* in labour productivity from year to year.

Model setup

We log-linearise the Cobb-Douglas regression and run the regression with three different specifications. The main model, which we present the results of in the main text, is specified as follows:

Main model: $Labour\ productivity_{it} = a_i + b_t + \beta_1 Capital\ per\ worker_{it} + \beta_2 Net\ stock\ of\ standards_{it} + \beta_3 Patents_{it} + \beta_4 Recession_{it} + \epsilon_{it}$

where $Labour\ productivity_{it}$ is the labour productivity in country *i* in year *t.* a_i and b_t are country-fixed effects and year-fixed effects respectively. These fixed effects are dummy variables, which are intended to control for factors that affect labour productivity, but which we cannot include in the model. Examples of variables which are not included in the model, but which these country-fixed and time-fixed effects may pick up, are the developments of institutions, increased human capital among workers, and so on. These are variables which are immeasurable and hard to include in the model. The fixed effects should pick up much of this and reduce bias in our estimate of the variable of interest (β_2), but there may still be omitted variable bias if the unincluded variables are correlated with the development of new standards.

The second model is similar to the first model but does not include time-fixed effects. Instead, it includes a *time trend*. This is the most common for studies analysing the effects of standards on a single country since they do not allow for the inclusion of time-fixed effects. It was also the chosen model for the Nordic study of 2018 (Menon Economics).

Model B: $Labour\ productivity_{it} = a_i + time\ trend + \beta_1 Capital\ per\ worker_{it} + \beta_2 Net\ stock\ of\ standards_{it} + \beta_3 Patents_{it} + \beta_4 Recession_{it} + \epsilon_{it}$

We consider that the results of the main model are more precise than that of Model B, but include Model B both as a robustness test and for comparison with other studies.

The final model we present here is on first-difference levels.

Model C: $\Delta Labour\ productivity_{it} = \beta_0 + \beta_1 \Delta Capital\ per\ worker_{it} + \beta_2 \Delta Net\ stock\ of\ standards_{it-1} + \beta_3 \Delta Patents_{it-1} + \beta_4 Recession_{it} + \epsilon_{it}$

Model C examines how the *change* in the explanatory variables affects the *change* in labour productivity. By taking the variables at first-difference, all the variables are stationary, and whether or not the variables at levels are cointegrated.

The interpretation of Model C differs somewhat from A and B. We here examine how the change in the stock of patents and standards *in the year before* affects the labour productivity in the next year. This is similar to the main model in EY, Menon & Knowence (2021). This means that we do not pick up the long-term effects of standards, but only the more immediate productivity effects.

Results

The table below shows the results of the three models.

Table 4: Results of the regression

	Main Model – Two-way fixed effects	Model B – Time trend	Model C – First difference
Capital per worker	0.324*** (16.96)	0.348*** (12.34)	0.3759*** (6.04)
Net stock of patents	0.0899*** (8.38)	0.0815*** (6.74)	0.0261 (1.38)
Recession	-0.038*** (-3.87)	-0.033*** (-3.81)	-0.0315*** (-8.2366)
Net stock of standards	0.061*** (3.72)	0.099*** (5.57)	0.037** (2.04)
Time trend	No	-0.006 (-0.64)	No
Country-fixed effects	Yes	Yes	Yes
Time effects	Yes	No	No
Number of observations	230 (6 countries * 50 years, with some countries lacking some data)	230 (6 countries * 50 years, with some countries lacking some data)	224 (6 countries * 49 years, with some countries lacking data)

**** p < 0.01, ** p < 0.05, * p < 0.1*

All three models show similar contributions of the capital per worker, varying between 0.324 and 0.376. This is also in line with what most empirical studies show, that capital consists of around one-third of the growth in productivity.

The net stock of patents has an elasticity of 0.08-0.09 in the main model and model B. This means that when the number of patents in the country increases by 1 percent, the labour productivity increases by around 0.08 percent. This is similar to what has been found in most other analyses. In model C, the coefficient for patents is positive, but not significant, which is logical, as the benefits of patents may take time to realise.

The main variable of interest is the net stock of standards. In the main model, we find a coefficient of 0.061. In model B, the value is higher, at around 0.099. Both of these are in the range of most studies, with the main model being slightly in the lower range. As we noted in chapter 1, the studies using panel data and time-fixed effects tend to find slightly lower contributions of standards than those using time trends. Both of these are valid models, but we consider that the main model, using two-way fixed effects, is more reliable.

In model C, the coefficient for the net stock of standards is 0.037. This is the relation between growth in the stock of standards and the growth in output *in the subsequent year.* It does not include growth that the standards may cause after the subsequent year. This is in other words only an estimate of the short-term effects. It is logical that this would be lower than the main model and model B. As a robustness check, it strengthens the conclusions of the main model.

The causality of the results

As mentioned earlier, past studies have indicated that standards and productivity operate in a form of "virtuous cycle", where an increase in one contributes to an increase in the other. This presents an issue in interpreting the results of the regression. When we observe that increased standardisation is associated with increased labour productivity, part of that may be that increased labour productivity increases the number of standards. This is a common issue for regression analyses, and a much-used methodology to attempt to examine whether there may be a causal relationship is *granger causality.*

Granger causality is about whether you can use one time-series to explain another. If the past changes in one time-series can explain the future of another, then that time-series can be said to *granger cause* the other. A classic example of granger causality is sunny weather and ice cream consumption. A normal OLS regression may tell you that when it is sunny, more ice cream is eaten. But that regression does not (in itself) tell you whether it is the weather causing people to eat more ice cream, or if more ice-cream eating improves the weather.

If we were to try to determine that it is in fact the weather causing the ice-cream-eating, and not the other way around, we could build a model to test granger causality. The model would check whether an improvement in the weather (such as going from cloudy to sunny weather, or an increase in temperature) in one hour is associated with an increase in ice-cream eating in the next hour. We would very likely find that the answer is yes. That would mean that the *past changes* in the weather can be used to explain the *future changes* in ice-cream eating. But if we were to do the opposite and check whether an increase in ice-cream eating in one hour is associated with better weather in the next hour, we would likely not find a relationship. Another way of saying this is that we expect that improved weather *granger causes* ice-cream eating, but that increased ice-cream eating does not *granger cause* improved weather.

We use this same logic for our productivity analysis, and check whether an increase in standards in one year can be used to predict an increase in productivity the next year. We also test the opposite: does an increase in productivity one year increase the stock of standards in the next year?

We use a Dumitrescu & Hurlin (2012) test for panel granger causality. The results of the test are shown in the table below:

Table 5: Results of the Dumitrescu & Hurlin (2012) test for panel granger causality

	Z-statistic (p-value)	Lag length[25]
ΔStock of standards -> ΔLabour productivity	4.214*** (0.000)	1
ΔLabour productivity -> ΔStock of standards	1.85* (0.0637)	1

**** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

The growth in the stock of standards in one year is found to granger cause an increase in labour productivity for at least one panel at the 1 percent significance. The other way around, labour productivity is only found to granger cause an increase in the stock of standards at the 10 percent level. There is in other words stronger support for that standards cause an increase in labour productivity, than that labour productivity increases the stock of standards.

This result is also intuitive. Creating standards takes a long time – often up to five years (EY, Menon & Knowence, 2021). It is therefore unlikely that changes in growth from one year to the next will affect the growth in the stock of standards. Standards, however, are likely to influence productivity as soon as the standards start being used.

A second concern with this form of analysis is that there may be other factors that affect both standards and productivity. This is often called *omitted variable bias.* There are many factors that affect labour productivity, many of which cannot be quantified. Some of these include worker education, improved rules and regulations, learning-by-doing and technological growth. If these variables are also correlated with the stock of standards, they may be the causal source of some of the association we observe between standards and productivity.

We try to avoid omitted variable bias by including both year-fixed effects and country-fixed effects in the main model. The country-fixed effects can control for consistent differences between the countries that do not change over time. By including these country-fixed effects in the model, we can account for the impact of these factors on labour productivity. The year-fixed effects, on the other hand, control for omitted variables that vary over time, and affect all the countries.

Using both year-fixed and country-fixed effects therefore *diminishes* omitted variable bias. This is the core reason why we include both in our main model, rather than a time trend as in model B. This method does not eliminate omitted-variable bias, however. The country and time effects do not adjust for unobserved variables which vary *both* over time and between countries.

Robustness tests – value added as dependent variable

As mentioned at the start of this appendix, there are two main dependent variables which are used in this form of analyses: l*abour productivity* or *output.* In this report, our main results are on *labour productivity,* in this robustness check we do the same with *output* as the dependent variable.

The regression with output as the dependent variable is:

[25] *The chosen lag length is found using BIC (Bayesian information criterion).*

Robustness model: $Output_{it} = a_i + b_t + \beta_1 Capital\ stock_{it} + \beta_2 Labour\ stock_{it} + \beta_3 Net\ stock\ of\ standards_{it} + \beta_4 Patents_{it} + \beta_5 Recession_{it} + \epsilon_{it}$

Where $Output_{it}$ is the aggregate value-added country i in year t, $Capital\ stock_{it}$ is the total capital stock, and $Labour\ stock_{it}$ is the number of employees.

Table 6: Results of the robustness model

	Robustness Model – Two-way fixed effects
Capital stock	0.315*** (16.26)
Labour stock	0.519*** (8.31)
Net stock of patents	0.0645*** (4.73)
Recession	-0.0399*** (-4.38)
Net stock of standards	0.0489*** (3.90)
Time trend	No
Country-fixed effects	Yes
Time effects	Yes
Number of observations	230 (6 countries * 50 years, with some countries lacking some data)
R2	0.907

**** p < 0.01, ** p < 0.05, * p < 0.1*

These results are very similar to the ones of the main model. The coefficient for the stock of standards of 0.0489 yields a very similar economic interpretation as the one in the main model. Standards' contribution from 1970 to 2019 is here 0.0489 * 7% = 0.34% per year. This is equal to approximately 20 percent of GDP growth over the period, which is very close to the result we found using labour productivity – which was also approximately 20 percent of GDP growth.

The coefficients for the capital stock and labour stock are also relatively similar to that of other productivity studies on OECD countries where the effect of a one percent increase in the capital stock is one third, and two thirds for labour.

This robustness test therefore provides support to the main model.

Appendix B: Methodology of the trade analysis

In this appendix, we briefly outline the econometric part of the gravity model. This can be read as a continuation of chapter 2.2.

Data

For trade data, we use data from the OECD's inter-country input-output database. This database is the OECD's foundation for analyses of global value chains and their trade in value-added database.[26] The database provides an estimate of the input from 45 industries in 66 countries to each of the 45 industries in the other 65 countries. It also contains estimates of the value added in each of these industries, for each year from 1995 through 2018.

These form the core of our model, together with the distance between the countries from the CEPI database. Together, these are the gravity aspects of our model.

Table 7: Industries included in trade analysis

Code	Industry	ISIC Rev.4
D01T02	Agriculture, hunting, forestry	01, 02
D03	Fishing and aquaculture	03
D05T06	Mining and quarrying, energy producing products	05, 06
D07T08	Mining and quarrying, non-energy producing products	07, 08
D09	Mining support service activities	09
D10T12	Food products, beverages and tobacco	10, 11, 12
D13T15	Textiles, textile products, leather and footwear	13, 14, 15
D16	Wood and products of wood and cork	16
D17T18	Paper products and printing	17, 18
D19	Coke and refined petroleum products	19
D20	Chemical and chemical products	20
D21	Pharmaceuticals, medicinal chemical and botanical products	21
D22	Rubber and plastics products	22
D23	Other non-metallic mineral products	23
D24	Basic metals	24
D25	Fabricated metal products	25
D26	Computer, electronic and optical equipment	26
D27	Electrical equipment	27
D28	Machinery and equipment, nec	28
D29	Motor vehicles, trailers and semi-trailers	29
D30	Other transport equipment	30
D31T33	Manufacturing nec; repair and installation of machinery and equipment	31, 32, 33
D35	Electricity, gas, steam and air conditioning supply	35
D36T39	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39
D41T43	Construction	41, 42, 43
D45T47	Wholesale and retail trade; repair of motor vehicles	45, 46, 47
D49	Land transport and transport via pipelines	49
D50	Water transport	50
D51	Air transport	51

[26] *https://www.oecd.org/sti/ind/measuring-interconnected-economies-2021.htm*

D52	Warehousing and support activities for transportation	52
D53	Postal and courier activities	53
D55T56	Accommodation and food service activities	55, 56
D58T60	Publishing, audiovisual and broadcasting activities	58, 59, 60
D61	Telecommunications	61
D62T63	IT and other information services	62, 63
D64T66	Financial and insurance activities	64, 65, 66
D68	Real estate activities	68
D69T75	Professional, scientific and technical activities	69 to 75
D77T82	Administrative and support services	77 to 82
D84	Public administration and defence; compulsory social security	84
D85	Education	85
D86T88	Human health and social work activities	86, 87, 88
D90T93	Arts, entertainment and recreation	90, 91, 92, 93
D94T96	Other service activities	94,95, 96
D97T98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97, 98

Model setup

We run two different estimation models on this data set. The first is a panel-data ordinary least-squares regression.

OLS model:

In the OLS model, the following regression is estimated:

$$Exports_{ijabt} = \alpha_{ia} + \gamma_t + \beta_1 Distance_{ij} + \beta_2 Value\ added_{iat} + \beta_3 Value\ added_{jbt} + \beta_4 Stock\ of\ standards_{iat} + e_{ijabt}$$

Where $Exports_{ijabt}$ are the exports from sector *a* in country *i* to sector *b* in country *j* in year *t*. $Distance_{ij}$ is the distance between country *i* and *j*. $Value\ added_{iat}$ is the value added in the selling industry, and $Value\ added_{jbt}$ is the value added in the buying industry. γ_t represents year-fixed effects, while α_{ia} are *country-industry* fixed effects for the seller. In this model, all variables have been log-linearised.

OLS-models such as this one were once the chosen way to run gravity models, until it was pointed out that this causes inconsistent estimation in the presence of heteroskedasticity by (Silva & Tenreyro, 2006). Since trade data naturally has a lot of zeros – especially when using sector data – this is an issue. They propose instead to model using a Poisson distribution, estimating with a Poisson Pseudo-Maximum Likelihood (PPML) technique.

PPML model:

The model specification is similar to the OLS model, but the estimation technique is somewhat different.[27] The interpretation of the coefficients is, however, the same. We utilise the "Gravity Modeling Environment" python package created by the United States International Trade Commission to estimate the PPML model.[28]

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[27] *For a relatively simple explanation of the differences, see https://www.scielo.br/j/rmj/a/qxCht7ddCpdqPS7J6WJgN5q/?lang=en*
[28] *https://www.usitc.gov/data/gravity/gme_docs/*

By including sector-industry and year effects, we are analysing the over-time increases of standardisation within sectors.

Results

The table below shows the results of the two gravity model specifications.

Table 8: Results of the two gravity models. Dependent variable: exports

	OLS model	PPML-model
Distance	-0.9877***	-1.3194***
Value added in selling industry	0.3655***	0.9102***
Value added in buying industry	0.8184***	0.6169***
Net stock of standards in selling industry	0.1189***	0.088**
Country-industry fixed effects	Yes	Yes
Time effects	Yes	Yes
Number of observations	14.7 million	14.7 million
R^2	0.57	

**** p < 0.01, ** p < 0.05, * p < 0.1*

There is a positive coefficient for the effect of standards on exports in both model specifications. The coefficient is just shy of 0.12 in the OLS model, and a little under 0.088 in the PPML-model. These coefficients are relatively similar to what Mangelsdorf & Blind (2015) find.[29] The model specifications differ somewhat on whether the buying or selling industry's size matters most. This difference is relatively common, and also found by for instance (Silva & Tenreyro, 2006).

We follow the advice of Silva & Tenreyro (2006) and consider that the PPML is the best estimate, and that the coefficient of 0.088 from standards on exports is our best estimate. The implication of these results is that a 1 percent increase in standards in an industry is associated with an increase in exports from that sector of around 0.088 percent.

Economic implications

The economic implication can be calculated either backward looking or forward looking. The backward looking estimate looks back, and calculates the economic contribution of standards per year as:

$$Contribution\ of\ standards_{it} = Exports_{it-1} * growth\ in\ stock\ of\ standards_t * coefficient$$

[29] Mangelsdorf & Blind look at intra-EU trade and differentiate between European and international standards. Their model specification differs from ours in several ways, but the interpretation is relatively similar. They find slightly lower coefficients for European standards than (0.059-0.077) than we do, but higher for international standards (0.13-0.21).

and then summarise this over the years to find the estimate for total contribution of standards to exports. With this calculation, the total benefit from 1995-2018 is around 73 billion euro, or 3.2 billion euro per year.

Going forward, we calculate the individual country values using the same equation as above, with *t* as 2022, and the growth in the stock of standards as 1.7 percent.

Appendix C: Methodology of the value chain analysis

In chapter 4, we discussed how standards affect the value chain. In this appendix we go through the methodology of the regression applied in that chapter

To analyse the value chain benefits of standardisation, we perform an analysis at the industry level. We perform a regression on labour productivity similar to the one in chapter 1, but with two key differences:

- Instead of looking at the countries as a whole, we run the model per industry.
- We include the stock of standards *among suppliers* as a factor. We estimate this based on the number of standards used in the industries that supply the main industry, weighted by how much they supply.

Concretely, the regression we run is:

$$\begin{aligned} Labour\ productivity_{ijt} &= a_{ij} + b_t + \beta_1 Capital\ per\ worker_{ijt} + \beta_2 Net\ stock\ of\ industry\ specific\ standards_{ijt} \\ &+ \beta_3 Net\ stock\ of\ standards\ among\ supplying\ industries_{ijt} + \beta_4 Patents_{ijt} + \beta_5 Recession_{it} \\ &+ \epsilon_{ijt} \end{aligned}$$

where $Labour\ productivity_{ijt}$ is the labour productivity in country *i* and industry *j* in year *t.* a_{ij} and b_t are country-industry-fixed effects and year-fixed effects respectively.

The $Net\ stock\ of\ industry\ specific\ standards$ is the number of standards which are solely related to the industry. We calculate this using a mapping between ICS-codes (the International Classification for Standards) and ISIC codes (the International Standard Industrial Classification). In other words, we map each standard to the industry it belongs to. This mapping has been developed by Menon over several standardisation projects, and is used for instance in EY, Menon & Knowence (2021).

The $\beta_3 Net\ stock\ of\ standard\ among\ supplying\ industries_{ijt}$ is a weighted measure of the number of standards in sectors supplying industry *j* in country *i* in year *t.* We calculate it the sum of standards that affect suppliers in sectors upstream in the value chain, weighted by the share of input provided by the respective upstream sectors. In simpler terms, it is a way to measure the influence of standards on the suppliers of a given sector. The calculation of takes into account the input from specific industries to a sector, the total upstream input, and the net stock of standards for a given industry in a given year. Concretely, it is calculated as:

$$Net\ stock\ of\ standard\ among\ supplying\ industries_{ijt} = \sum_{n=1}^{N} Share\ of\ input\ coming\ from\ industry\ n * Net\ stock\ of\ industry\ specific\ standards_{int}$$

where j is the industry, t is the year, and *i* is country, and *n* is supplying industry.

The purpose of the $Net\ stock\ of\ standard\ among\ supplying\ industries$ is to provide insight into the impact of standards on different sectors and industries within the value chain.

We perform this analysis for 25 industries, for the six countries, from 1970 to 2019. The sectors chosen were the ones with the most detailed data available going back to the 1970s for the six countries. They are shown in the table below.

Table 9: Industries included in the value-chain analysis

Code	Industry
D01T03	Agriculture, hunting, forestry and fishing
D05T09	Mining and quarrying
D10T12	Food products, beverages and tobacco
D13T15	Textiles, wearing apparel, leather and related products
D16T18	Wood and paper products, and printing
D22T23	Rubber and plastics products, and other non-metallic mineral products
D24T25	Basic metals and fabricated metal products, except machinery and equipment
D26T27	Electrical, electronic and optical equipment
D31T33	Furniture; other manufacturing; repair and installation of machinery and equipment
D35T39	Electricity, gas and water supply; sewerage, waste management and remediation activities
D41T43	Construction
D45T47	Wholesale and retail trade, repair of motor vehicles and motorcycles
D49T53	Transportation and storage
D55T56	Accommodation and food service activities
D58T60	Publishing, audiovisual and broadcasting activities
D61	Telecommunications
D62T63	IT and other information services
D64T66	Financial and insurance activities
D68	Real estate activities
D69T71	Legal and accounting activities; activities of head offices; management consultancy activities; architecture and engineering activities; technical testing and analysis
D72	Scientific research and development
D73T75	Advertising and market research; other professional, scientific and technical activities; veterinary activities
D77T82	Administrative and support service activities
D84T88	Public administration and defence; compulsory social security; education; human health and social work activities
D90T93	Arts, entertainment and recreation

Results

The table below shows the coefficients of the value chain model.

Table 10: Results of the value chain regression

	Value chain analysis
Capital per worker in the industry	0.611*** (23.2)
Stock of patents in the industry	0.0347*** (4.32)
Stock of standards in the industry	0.056*** (8.45)
Stock of standards among suppliers	0.087*** (8.44)

Recession	-0.0514** (2.58)
Country-industry fixed effects	Yes
Time effects	Yes
Number of observations	5064 (6 countries * 50 years * 25 industries, with some countries and industries lacking some data)
R2	0.92

**** p < 0.01, ** p < 0.05, * p < 0.1*

The table shows that both the stock of standards in the industry and the stock of standards among suppliers have positive and statistically significant coefficients (0.056 and 0.087, respectively). This supports the hypothesis that standardisation benefits both those who standardise and their customers.

A concern in regressions as this is sometimes multicollinearity. We perform VIF-tests for multicollinearity which confirm this is not a problem (VIF-score less than 5 for all variables)

As a robustness test, we also perform the analysis with value added as the dependent variable. That is:

$$Output_{ijt} = a_{ij} + b_t + \beta_1 Capital\ stock_{ijt} + \beta_3 Net\ stock\ of\ industry\ specific\ standards_{ijt} + \beta_4 Net\ stock\ of\ standards\ among\ supplying\ industries_{ijt} + \beta_5 Patents_{ijt} + \beta_6 Recession_{it} + \epsilon_{ijt}$$

Where $Output_{ijt}$ is the aggregate value-added country *i* and sector *j* in year *t*, $Capital\ stock_{ijt}$is the total capital stock, and $Labour\ stock_{ijt}$ is the number of employees.

Table 11: Results of the robustness test for the value chain regression

	Robustness Model – Value chain analysis
Capital stock	0.5453*** (19.9)
Labour stock	0.164*** (5.6)
Stock of patents in the industry	-0.003 (-0.02)
Stock of standards in the industry	0.049*** (6.90)
Stock of standards among suppliers	0.788*** (6.98)
Recession	-0.0507** (2.56)
Country-industry fixed effects	Yes
Time effects	Yes

Number of observations	5064 (6 countries * 50 years * 25 industries, with some countries and industries lacking some data)
R2	0.89

For the standards-related variables, the results of the robustness test are very similar to the main analysis. Both the stock of industry standards and the stock of standards among suppliers contribute, and the value for suppliers is slightly higher. This adds support to the findings of the main value chain analysis.

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